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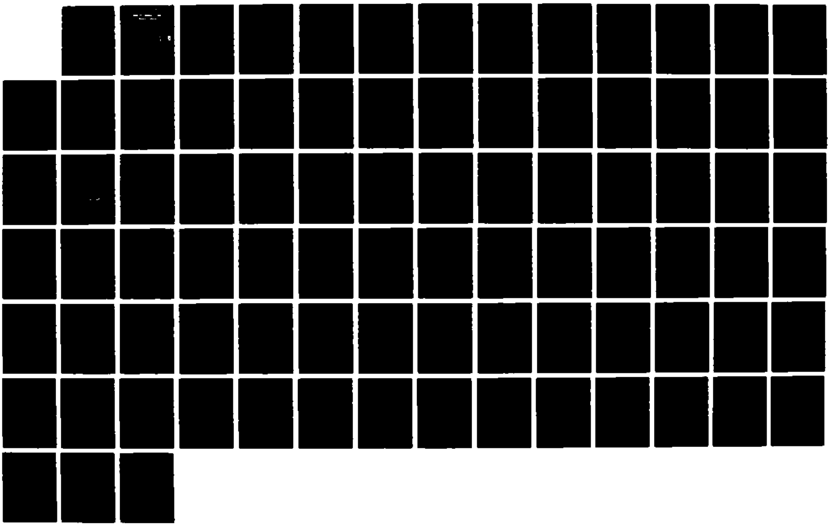

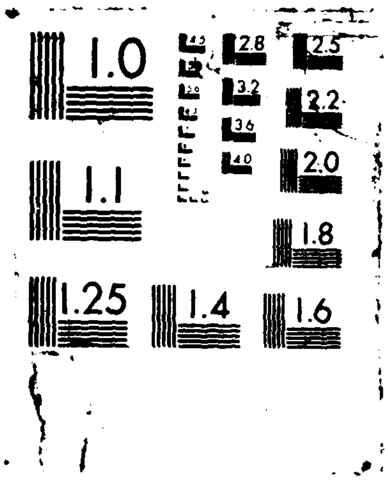
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Monterey, California

THESIS

COST ESTIMATING METHODS
ASSOCIATED WITH A STATE-OF-THE-ART
EXTENSION
AT LOCKHEED MISSILE AND SPACE COMPANY, INC.

by

John I. Morris

December 1987

Thesis Advisor: W.R. Greer, Jr.

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The present Department of the Navy Budget process does not appear to include a completely satisfactory method by which to estimate the costs associated with programs requiring advancement of technology beyond the current state-of-the-art (SOA). Navy budget analysts could benefit from an understanding of how cost estimating is accomplished in the defense industry. With these insights, Navy estimating methods might be enhanced by allowing for the validation of the various estimating methods and inclusion within the Navy estimation process as appropriate. This research examines the methods used by a major defense contractor in estimating the development costs associated with a specific state-of-the-art extension project. The study, conducted through the use of personal interviews and examination of project cost data and information, determined that a combination of techniques was utilized within a formalized contractor-specific estimation process. These techniques included engineering estimates, reference to similar projects previously accomplished, and parametric modeling.

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Cost Estimating Methods Associated with a State-of-the-Art Extension at Lockheed Missile and Space Company, Inc.

by

John I. Morris
Lieutenant, Supply Corps, United States Navy
B.S. , San Diego State University, 1978

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Author: John I. Morris

Approved by: Willis R. Greer, Jr., Thesis Advisor

L. R. Jones, Second Reader

David R. Whipple, Chairman
Department of Administrative Sciences

James M. Fremgen,
Acting Dean of Information and Policy Sciences

ABSTRACT

The present Department of the Navy Budget process does not appear to include a completely satisfactory method by which to estimate the costs associated with programs requiring advancement of technology beyond the current state-of-the-art (SOA). Navy budget analysts could benefit from an understanding of how cost estimating is accomplished in the defense industry. With these insights, Navy estimating methods might be enhanced by allowing for the validation of the various estimating methods and inclusion within the Navy estimation process as appropriate. This research examines the methods used by a major defense contractor in estimating the development costs associated with a specific state-of-the-art extension project. The study, conducted through the use of personal interviews and examination of project cost data and information, determined that a combination of techniques was utilized within a formalized contractor-specific estimation process. These techniques included engineering estimates, reference to similar projects previously accomplished, and parametric modeling.

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I. INTRODUCTION

A. RESEARCH OBJECTIVE

Development of new and improved weapon systems requires technology to expand its boundaries. The Department of the Navy is a prime requirer of these state-of-the-art (SOA) technological advancements. However, the budgetary impacts of SOA extensions are often greater than anticipated. The Navy budget development process does not appear to include an adequate methodology for determining what extending an existing weapon system "should cost". To realistically budget for SOA extensions, Department of the Navy budget analysts should better understand how cost estimating for SOA extension projects is currently accomplished by the individual(s) responsible for advancing this technology, i.e. the defense industry. Navy budget analysts can use this knowledge to test the accuracy of the various cost estimating techniques. The purpose of this research was to gain greater insight into how one major corporation involved in Navy contracting forecasts or predicts the development costs associated with extending technology beyond current bounds.

B. RESEARCH QUESTIONS

Given the preceding objective, the following primary research question was posed: What methods were employed by a major Department of the Navy contractor to predict the development costs associated with an actual state-of-the-art (SOA) extension project?

In addition, the following subsidiary research questions were considered relevant in thoroughly addressing the primary question:

1. What were the expected costs, actual costs, and variances experienced during the development of the SOA extension project?
2. What were the reasons for the variances experienced?

3. Which development cost categories had the most effect on total project cost?, i.e. what were the "cost drivers"?
4. What organizational design or structure was utilized during the SOA project; and how does that design affect cost management?

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

1. Scope

The research focused on the actual cost estimation techniques utilized by a Department of the Navy contractor in the development of an SOA extension project. No effort was made to consider the justification or fairness of profit margins or return on investments; rather emphasis was placed on determining the development costs associated with the SOA extension. In addition, the study did not attempt to construct or suggest any analytical models for predictive or explanatory purposes. The basic effort was aimed at producing an accurate description of the quantitative and qualitative development costing methods employed by a particular defense contractor. There has been no prior research directly addressing the primary research question. Consequently, the researcher relied upon personal interviews with key contractor personnel and the collection and examination of cost data at the contractor site. The results of this study should provide the reader with a complete understanding of the actual process involved and results achieved by a specific contractor on an actual SOA extension project.

2. Limitations

The study is limited to the observations and conclusions reached by the researcher on an actual SOA extension project conducted by a Department of the Navy contractor. An inherent limitation of this study is that direct transferability of the data, findings, and observations to other applications may be inappropriate. The actual SOA project studied involved the design , construction, and operational testing of a single final product. Production costs are seen as incorporated in the development costs and are therefore not considered separately.

3. Assumptions

The presumption throughout this research effort is that the Department of the Navy contractor routinely employs a method of estimating development costs associated with SOA extension projects. No overly stringent assumptions were made concerning the readers in-depth knowledge of cost accounting, quantitative techniques for cost estimation, or the acquisition/contracting process within the Department of Defense.

D. RESEARCH METHODOLOGY

The research methodology utilized in this effort consisted of a case study involving the cost estimating processes employed by Lockheed Missiles and Space Company in development of the Control System Test Vehicle (CSTV) project. Personal interviews and documentation provided by the Naval Plant Representative Officer (NAVPRO) , Lockheed Corporation, Sunnyvale, California, and the Lockheed Missiles and Space Company, provided the primary input for the research effort. Additional background research consisted of examining the literature base thorough the Defense Technical Information Center (DTIC), the Defense Logistics Studies Information Exchange (DLSIE), and various publications and journals.

E. ORGANIZATION OF THE REPORT

Chapter II begins with a discussion of relevant definitions and concepts found in the literature; such as, what constitutes an extension of the current state-of-the-art; what items are categorized as development costs; and the differences between cost growth involving contract modifications and true cost overruns or variances. Chapter II continues with a brief discussion of the types of contracts used to support SOA extension projects. Generic cost estimation techniques and methods used by the Department of the Navy and the defense manufacturing industry are also considered. Chapter III introduces the Control System Test Vehicle (CSTV) itself and the cost estimating methods employed by LMSC in estimating

the project's development costs. Chapter III also includes a description of the organizational structure and working relationships formed within LMSC to complete the Control System Test Vehicle (CSTV) project. Chapter IV presents the cost data collected. Variances between predicted and actual costs are examined along with the causative factors involved. Cost categories that exhibited significant influence over total project cost are identified and discussed at the end of Chapter IV. Chapter V summarizes the principle findings of the study, conclusions reached, and practical recommendations made. In addition, areas for further research are suggested.

II. BACKGROUND REVIEW AND THEORETICAL FRAMEWORK

A. INTRODUCTION

The purpose of this chapter is to provide the reader with an overall perspective of the environment in which the research was conducted. The chapter begins by examining and defining relevant concepts and terminology associated with technical advancements in state-of-the-art weapons systems. The important difference between cost deviations due to modifications in the basic contract and true cost overruns is then discussed. What follows is a description of a key project management tool used within the contracting effort; the Contract Data Requirements List (DD Form 1423). A brief look at the major types of government contracts awarded to state-of-the-art extension projects provides the reader with a general understanding of the incentives and policies under which a development contract is administered. The two basic approaches currently used by the Department of the Navy to estimate development costs are then introduced. Finally, the most widely accepted generic cost estimating techniques currently in use by the defense industry will be presented.

B. DEFINITIONS AND CONCEPTS

1. State-of-the-Art (SOA) Extension

Before any discussion, a definition of what constitutes a state-of-the-art (SOA) extension, must be established. Although, an exact definition of the term is difficult to obtain, synonymous definitions are found in the technical literature. James R. Bright and Milton E. F. Shoeman describe the process of technological innovation as follows:

> The *process of technological innovation* is a phase intended to embrace those activities by which *technical knowledge is translated into a physical reality and is used on a scale*

having substantial societal impact. This definition includes more than the act of invention. It includes initiation of the technical idea and acquisition of necessary knowledge, its transformation into useable hardware (or a process), its introduction into society, and its diffusion and adoption to the point where its impact is significant. [Ref. 1:p.48]

Perhaps the most precise definition of "state-of-the-art" technology and technological advancement encountered by the researcher was given by G.N. Dodson and C.A. Graves of General Research Corporation as follows:

The state-of-the-art is the state of best implemented technology reflected in the most recently [applied] physical and performance characteristics. Our overall hypothesis concerning the advancement in the state-of-the-art is more precisely stated as the developmental design characteristics, (or related to the advance of these characteristics) represented in relation to the best that has been previously implemented. [Ref. 2:p.1]

With the above ideas in mind, the researcher has adopted the following as an acceptable definition of state-of-the-art extension: advancements in applied technology, through the unique combination of known and newly developed technological methods, to produce a previously nonexistent product. Work currently in progress on the Strategic Defense Initiative (SDI) program provides numerous examples of advancing technology through state-of-the-art extensions. The Exoatmospheric Reentry Vehicle Interception System (ERIS) program [1] under development at Lockheed Corporation combines technologies developed during previous projects (propulsion, ordnance, structural) with current and yet undeveloped technology (advanced avionics, engineering integration) to produce a currently non existent defensive missile system.

2. Development Cost

As stated in Chapter One, the researcher has limited the scope of the study exclusively to considerations of development costs. It may now be helpful to define

[1] The ERIS program is currently being developed for the U.S. Army Strategic Defense Command (USASDC) at an estimated cost of $500M. The ERIS program will consist of a system of ground launched , non-nuclear missiles, whose purpose will be to intercept and destroy incoming ICBMs.

precisely what costs are included within this category. Development efforts can be viewed (within the Department of Defense) as a subset of a broader category of activity generally referred to as Research, Development, Test, and Evaluation (RDT&E). According to the Department of the Navy Budget Guidance Manual, the overall function of RDT&E is to provide the capabilities needed to most effectively carry out the tasks required to successfully complete the mission of the Navy [Ref. 3]. Moreover, RDT&E programs should focus on (1) determining what technologies are possible, and (2) applying what is technically possible, to develop workable solutions that satisfy mission requirements [Ref. 3]. The costs associated with these objectives are categorized as RTD&E costs. For the purpose of this study development costs will refer to all costs that are associated with the design and testing of a new operational capability [2] .

3. Cost Growth vs. Cost Overrun

In a subsequent chapter, frequent reference will be made to the terms "cost growth" and "cost overrun" (or variances). There is often confusion regarding these two concepts; and therefore a tendency to erroneously use the two terms interchangeably. Cost growth refers to change in current cost estimates over a previously established base figure. Therefore, changes in the total estimated cost of a program should correctly be called "cost growth". Contract modifications, which are simply changes to the original specifications delineated in the contractual agreement, are a major reason for cost growth in a contract. Cost overruns on the other hand, denotes the difference between actual cost experienced and the estimated cost delineated in the contract; i.e. the estimated costs remain unchanged. [Ref. 4]

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2 As will be seen in Chapter Three, the development costs associated with the CSTV project also includes the cost to produce the single operational test vehicle.

4. Types of Government Contracts

Although the underling purpose of this paper is not to explore the various categories of contractual agreements that exist between government and private industry, it is useful for the reader to acquire a broad understanding of the major types of contracts that are utilized in support of state-of-the-art extension projects. In general, a contract can be seen as an offer and acceptance backed by legal considerations. The types of contracts normally used to support RDT&E efforts (and thus include state-of-the-art extension projects) are discussed below.

Cost contract- A cost contract calls for the government to pay all allowable costs involved in executing a given research project. The contractor receives no fee. This type of contract establishes an estimate of the total costs as defined in the contract for purposes of (1) obligating current funds, and (2) establishing a ceiling beyond which the contractor cannot proceed (except at his own risk) without prior approval. [Ref. 5:p. 16-3]

Cost-Sharing contract- Under a cost-sharing contract the contractor is reimbursed for an agreed portion of his allowable costs, not to exceed an established ceiling without fee. [Ref. 5: p. 16-3]

Cost-plus-fixed-fee contract- The cost plus a fixed fee contract is similar to the cost contract in that it provides for payment to the contractor of all allowable costs as defined in the contract, and establishes an estimate of the total cost. In addition, it provides for the payment of a fixed fee based primarily on the nature of work to be performed [Ref 5:p.16-3]. As will be seen in subsequent chapters, the CSTV project involved this specific type of contractual agreement.

Cost-plus-incentive-fee contract- The cost plus an incentive fee contract is a cost reimbursement type agreement with provision for a fee which is adjustable by formula in accordance with the relationship which total allowable costs bear to target costs. Under this

type of contract, there is negotiated initially a target cost, a target fee, a minimum and maximum fee, and a fee adjustment formula. Factors other than cost, including performance and progress, can also be used as a basis for contract incentive. [Ref. 5:p. 16-3]

Fixed-price-incentive contract- The fixed price incentive contract includes a provision for the adjustment of profit and the establishment of the final contract price by a formula based on the relationship which final negotiated total cost bears to target costs. Under this type of agreement, target cost, profit, price ceiling, and a formula for establishing final profit and price are negotiated prior to execution. [Ref. 5:p. 16-3]

Firm-fixed-price contract- The firm fixed price contract provides for a price which is not subject to any adjustment by reason of the cost experience of the contractor in performance of the contract. This type of agreement, when appropriately applied, places maximum risk upon the contractor. Because the contractor assumes full responsibility, in the form of profit or loss for all costs under or over the firm fixed price, he has a maximum profit incentive for effective cost control and contract performance. The firm fixed price contract is suitable for use in procurements in which reasonably definitive design and/or performance specifications are known and fair and reasonable prices can be established at the outset. This type of contract is also suitable for level-of-effort work in which the contractor is compensated for expending his best effort at fulfilling program requirements. [Ref. 5:p. 16-3]

5. Contract Data Requirements List (DD Form 1423)

A presentation of the Contract Data Requirements List (CDRL) is appropriate here since it will be referred to extensively in subsequent chapters. In accordance with DOD instruction 5010.12, all government contracts which require data as a deliverable item must have these requirements delineated in a Contract Data Requirements List (CDRL). This documentation must state all data requirements that the contractor is to furnish. Some of the

data that is included are: technical status reports, cost and schedule reports, test results, technical manuals, design drafts and specification listings, and specific analyses. For many of these items, an approved Department of Defense identification number, known as a Data Item Description (DID), exists and must be cited. [Ref. 6:p. 4-52]

C. NAVY COST ESTIMATION METHODS

Inherent in all Department of Defense management decisions is the obligation to provide for the highest mission capability possible within the limits of available resources. The policy on overall resource allocation is stated in Department of Defense directive 5000.1:

> A cost effective balance must be achieved among acquisition costs, ownership costs...., and system effectiveness in terms of mission to be performed. [Ref. 7:p. 1]

Throughout the Department of the Navy, there is much importance placed on accurately estimating the probable development costs associated with all program acquisitions, including state-of-the-art extension projects. Cost estimating efforts are found in every phase of the Navy planning, programming, and budgeting cycle (PPBS) as well as phases within the acquisition process. However, emphasis on cost estimating efforts is particularly predominant in the planning phase of the PPBS. The accurate estimation of development cost is an essential prerequisite to realistic budgeting for weapon systems.[Ref. 8:p.3]

The development of cost estimates for a particular program is the responsibility of the Principal Developing Activity (PDA). At the same time, independent cost estimates are produced by the Director of Navy Program Planning (OP-90). Finally, the DOD Cost Analysis Improvement Group (CAIG) independently conducts a comprehensive review and evaluation of both estimates and provides this information to the Joint Requirements and Management Board (JRMB). The primary costing methodologies that are employed by these activities are (1) to work from detailed estimates of the cost of work packages to

derive the overall estimate, and/or (2) to start from the overall characteristics of the particular system and estimate the probable development costs by deductive reasoning. [Ref. 8:p. 10]

The detailed estimation approach is referred to as the Engineering or "bottom up" method. It involves breaking down the project into separate and identifiable segments of work. The breakdown is accomplished by means of a Work Breakdown Structure (WBS). The WBS is defined in Military Standard 881A as:

> ... a produce-oriented family tree composed of hardware, services and data which results from project engineering efforts during the development and production of a defense materiel item, and which completely defines the project/performance. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplished to each other and to the end product. [Ref. 9]

With the task elements of the project identified in terms of the work breakdown structure, development costs are estimated using available historical cost data and totalled at each level. An overall developmental cost estimate consists of a summation of the individual development costs of each task element. [Ref. 8:p. 8]

The second major cost estimation technique used by the Department of the Navy consists of initially viewing the project at the macro level. Specific physical and/or performance characteristics sought; such as size, complexity, or performance level, are then identified. Finally, derived relationships known as Cost Estimating Relationships (CER's) are applied to the parameters of the project to develop a total development cost estimate. This method is known as Parametric or "Top Down" modeling. The method (or combination of methods) used by the Navy depends on various factors including the availability of relevant historical data and/or the complexity of the project being considered. [Ref. 8:p.9]

D. INDUSTRY-WIDE COST ESTIMATION METHODS

In subsequent chapters, reference is made to cost estimation techniques and processes currently employed by Department of Defense contractors. The parametric and engineering models were discussed in the preceding section. These two models are extensively employed within private industry as well. What follows is a discussion of two additional models that are used to estimate the development costs associated with state-of-the-art extension projects.

1. Associated Program

The associated program method of cost estimation attempts to compare the total development costs of a current project with that of a technically representative program previously completed. If the two projects are not completely identical, an attempt is made to adjust the cost estimate to reflect similarities and differences between the two projects. Because of the difficulty in obtaining a previous project that can satisfactorily represent the current project, the associated program method is considered the least accurate method of estimation. It is most often used to obtain initial "starting points" early in the conceptual phase of the acquisition process and when little or no historical cost data over a wide range of programs is readily available. [Ref. 10:p. 2-70]

2. Similar-To Method

The similar-to or analog method of cost estimation closely resembles the associated program method but with an important difference. Rather than basing the estimate on the cost experience of a single representative program, a historical database consisting of actual tasks and their associated costs, is utilized to estimate the development cost of the current project [Ref. 10:p. 2-70]. The following example helps clarify the point.

> The use of new structural material for aircraft often requires the development of special cutting and forming techniques with manufacturing labor requirements that differ significantly from those based on sample primarily aluminum airframes. Faced with this problem when titanium was first considered for use in airframe manufacture, airframe

companies developed standard-hour values for titanium fabrication on the basis of shop experience in fabricating test parts and sections. [Ref. 11]

The cost estimate for fabricating titanium airframes was based on an analogous task previously experienced when titanium test parts and sections were fabricated. The analogous experience does not come from a single past project; as task experience gained from numerous projects constitute the historical cost data. In fact, the similarity of the end products is not always overly relevant; what is important are the similar tasks themselves.

Table I compares the major cost estimation methods currently in use by the Department of the Navy and defense industry contractors. An important point to observe is that each of these methods have inherent advantages and disadvantages and are used either singularly or in combination depending on various considerations. Table II illustrates the results of the Booze, Allen and Hamilton study of prevalent cost estimation techniques as related to various phases of the acquisition process [Ref. 12]. As can be seen, there is evidence to suggest that the cost estimating methods employed throughout industry are not restricted to a single method,but rather, are used in concert with one another to generate a development and production cost estimate. This concept will be seen in a later chapter when the Lockheed Missiles and Space Estimating System Description (ESD) is presented.

E. CHAPTER SUMMARY

This chapter outlined several concepts considered relevant in estimating the cost of state-of-the-art extension projects. A workable definition of state-of-the-art extension was established followed by a brief look at development programs and development costs. The important difference between cost growth and cost overruns (variances) was then presented. Various categories of government contracts used in the Research, Test, Development, and Evaluation (RTD&E) effort was generally reviewed. Finally, a description of the most prevalent cost estimating methods utilized by the Department of the Navy and the Defense Industry was presented.

TABLE I
COMPARISON OF ESTIMATION METHODS *

Methodology	Characteristics	Pluses	Minuses
ASSOCIATED PROGRAM	Based on total actuals from technically representative program modified by economic & complexity factors	+ Provides early quick-look + Traceable to historical costs	- Not sensitive to technical/programmatic details and differences - Can't provide cost element breakdown
PARAMETRIC MODELING	Derived from relationships of cost to non cost physical or performance	+ Can be applied when system characteristics are known + Can identify cost drivers	- Not traceable to actual history - Can't easily validate algorithm
SIMILAR-TO MODELING	Generated from historical cost data using tasks or equipment similar to proposed/concept design	+ High degree of accuracy + Provides cost breakdown in WBS format + Models use own contractors data base	- Requires relatively mature design - Requires maintenance of good historical data base - Requires cost analysts with extensive company experience
ENGINEERING or "BOTTOM UP" MODELING	Detailed functional & cost element estimates prepared at lowest practical level of task and design definitions	+ High degree of accuracy + Provides WBS element costs to lowest level + Uses available historical cost data	- Requires detailed design description - Time consuming and expensive to generate - Can't use as stand alone approach

* Source: Information received during interview with LMSC Estimating Systems Manager, Mr. T. Castro on 24 September 1987.

TABLE II

INDUSTRY COST ESTIMATING METHODS AND MOST PREVALENT USE BY ACQUISITION PHASE

	CE	D/E	EARLY FSD	LATE FSD	PRODUCTION
PARAMETRIC	P	S	S	N/A	N/A
ANALOGY	S	P	S	N/A	N/A
ENGINEERING	N/A	S	P	P	P

P= Primary Method(s)
S= Secondary Method(s)
N/A= Not Typically Used

CE= Concept & Exploration Phase
D/E= Demonstration & Validation Phase
FSD= Full Scale Development Phase

III. HISTORICAL PERSPECTIVE, PROGRAM STRUCTURE AND COST ESTIMATION PROCESSES

A. INTRODUCTION

This chapter focuses on the specific state-of-the-art extension project chosen for the study, i.e. the Control System Test Vehicle (CSTV) developed by Lockheed Missile and Space Company. It begins by describing what the Control System Test Vehicle is, what it was designed to accomplish, and what Lockheed Missiles and Space Company's contractual responsibilities are.The following section of the chapter describes the overall Lockheed Missiles and Space Company's (LMSC) management structure, lines of communication and authority, and the specific project structure incorporated during the completion of the Control System Test Vehicle (CSTV) project. The final section of the chapter examines the processes and methods utilized by Lockheed Missiles and Space Company in estimating the development costs associated with the state-of-the-art extension project.

B. SYSTEM DESCRIPTION

Prior to the age of nuclear submarines, the general understanding of submarine hydrodynamics was such that even though maneuvering responses were not always as expected, the inherent dangers were few because of the slower operating speeds then experienced. However, with fleet introduction of high performance nuclear powered attack submarines, in particular the USS Los Angeles (SSN-688), these operating speeds were greatly increased as well as the achievement of maneuvering techniques previously unattainable. Extrapolation of data from computer simulation and small-scale models to determine the effect of submarine design modifications on the performance, stability and control were found to yield less than reliable results. The ability to safely and fully exploit the

high performance potential of modern high speed submarines required a full understanding of all factors influencing their maneuverability and ability to recover from casualty situations. To this end the Navy desired an improved method whereby data pertaining to the control, stability, and maneuverability characteristics of the Los Angeles class attack submarine could be gathered, analyzed, and understood.

On July 25, 1978, Lockheed Missiles and Space Company formally responded to the Navy's request for proposal (RFP number N00024-78-R-5352S) by submitting a technical, management, and cost proposal calling for the design, construction, and test of a control system test vehicle and related support equipment. What Lockheed Missiles and Space Company proposed with the introduction of the Control System Test Vehicle (CSTV) was the ability to provide a more efficient and effective means of assessing maneuvering responses to control inputs with an accuracy never before attained. The Lockheed Missiles and Space Company concept involved the development of a 1/12 scale model of the Los Angeles (SSN 688) class nuclear submarine. It also included the accessories and support equipment needed for its operation and maintenance. Government furnished control and instrumentation components were to be contained within a pressure hull and fully integrated with all other vehicle systems to form an unmanned, free running, self-propelled and controlled vehicle. The Control System Test Vehicle (CSTV) was designed to operate in fresh or salt water to depths of 300 to 1,200 feet. The project was considered by Lockheed Missiles and Space Company (LMSC) to be a technically risky endeavor. This was primarily due to the fact that much of the technology needed to successfully complete the project would have to be integrated in a way never before attempted. In addition, the integrated electronics and government furnished computer hardware would have to be fitted into the confined space of the pressure hull. Furthermore, advancements in technologies of the time were required in the areas of advanced hydrodynamics, propellers, structures, fabricating

materials, anticorosion and fouling, and submerged mechanical and electronic component integration.

On October 10, 1978, LMSC submitted its "Best and Final Offer" proposal to the Navy program manager (Naval Sea Systems Command) with a cost plus fixed fee contract (CSTV contract N00024-79-C-5356) valued at $1,799,385 being awarded to LMSC on December 29, 1978.

C. CONTRACTOR PROJECT RESPONSIBILITIES

The responsibilities and obligations of LMSC in regards to the CSTV project can be found by referring to the Statement of Work (SOW). The complete SOW is included as Appendix A. In broad terms, Lockheed Missiles and Space Company, Inc., was the prime contractor for the project and was directly responsible for accomplishing the following tasks:

1. The design and construction of one (1) Control System Test Vehicle (CSTV)
2. The design and construction of a set of support equipment
3. The test and evaluation of the vehicle to ensure proper operation
4. To perform system engineering activities aimed at coordinating and controlling development and ultimate project completion

D. ORGANIZATIONAL STRUCTURE

For the Control System Test Vehicle Project, Lockheed Missiles and Space Company (LMSC) drew upon the management success previously realized by the Lockheed California Company located in Burbank, California (a wholly independent subsidiary of the parent company, The Lockheed Corporation) and it's highly successful "Skunk Works" project team approach. Project organizations structured along task-team lines are utilized by all Lockheed subsidiaries for many of their advanced development or state-of-the-art extension programs. The CSTV project was therefore a fitting candidate for this project team approach. The decision to organize the project in this manner was based on an internal

assessment of management elements seen as vital to the success of the CSTV project. These management elements are presented as follows:

TABLE II

MANAGEMENT ELEMENTS SEEN AS VITAL TO THE CSTV PROJECT

* Authorized Project Manager, reporting to a Company Officer, full authority for his Project
* Establish a small and highly competent project organization
* Use a flexible and low cost drawing system that expedites and controls changes
* Keep documentation to a minimum, meeting CDRL requirements
* Maintain continuous status of the project visible to management
* Establish an austere and fully compliant Quality Assurance Program
* Support and participate in post-delivery testing to maintain competence for follow-on support
* Earn customer trust with integrity and close cooperation and liaison
* Obtain customer understanding and concurrence at the start of the contract on methods and procedures for controlling government furnished equipment and technical data
* Limit project access and the number of support personnel required

The utilization of a project team approach was beneficial in controlling previous SOA project costs. Lockheed Corporation believes that the small number of people within a project team significantly improves management coordination and control. Furthermore, cost control responsibilities within the project manager's organization greatly increases cost awareness and the desire for controlling costs.

1. Overall Corporate Structure

The overall organizational structure of the Lockheed Corporation is depicted in Figure 1, which also shows the relationship between the Control System Test Vehicle project team and the other organizational elements of Lockheed. The Lockheed Missiles and Space Company, Inc. (LMSC) is headquartered in Sunnyvale, California. Within LMSC, the Research and Development Division (R&DD) is responsible for developing new and advanced products that take maximum advantage of the skills available within the corporation. Ocean Systems is one of the major product lines in R&DD. The CSTV project management team was placed directly within Ocean Systems. Within this structural arrangement, the CSTV project team was authorized, and in fact encouraged, to draw upon all three major functional organizations within LMSC (Missile Systems, Research and Development, and Space Systems) for technical development support and expertise.

2. Lines of Communication and Authority

As was previously stated, Figure 1 illustrates the placement of the CSTV project within the overall Lockheed organization. This arrangement provided direct access to top executives within the corporation. This directness in communications was confirmed in several personal interviews with LMSC managers involved with the CSTV project and was considered an important advantage during the entire project. Also of significance was the authority given to the project management team during development of the CSTV project. Again, this seemed to be a positive aspect of the management structure, as expressed by the individuals associated with the project.

3. CSTV Project Team Structure

The overriding concept of the CSTV project management effort, i.e. tight project controls, and full authority and responsibility of the project manager, is reflected in the project team organizational chart (Figure 2). The project team structure can be seen as a

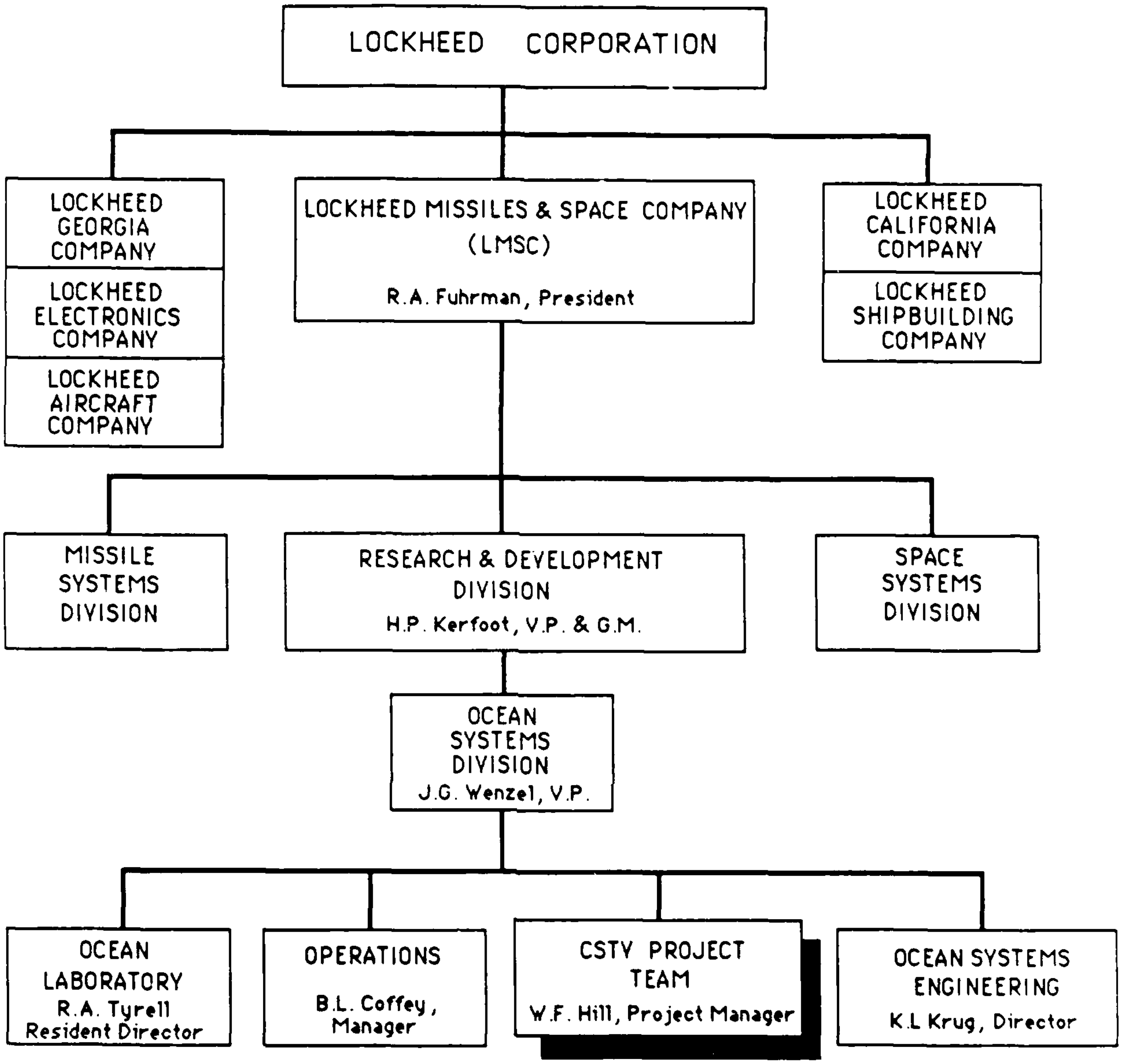

Figure 1. Placement of the CSTV Project Team within Lockheed

Source: LMSC Management proposal no. D085091 of 25 July 1978

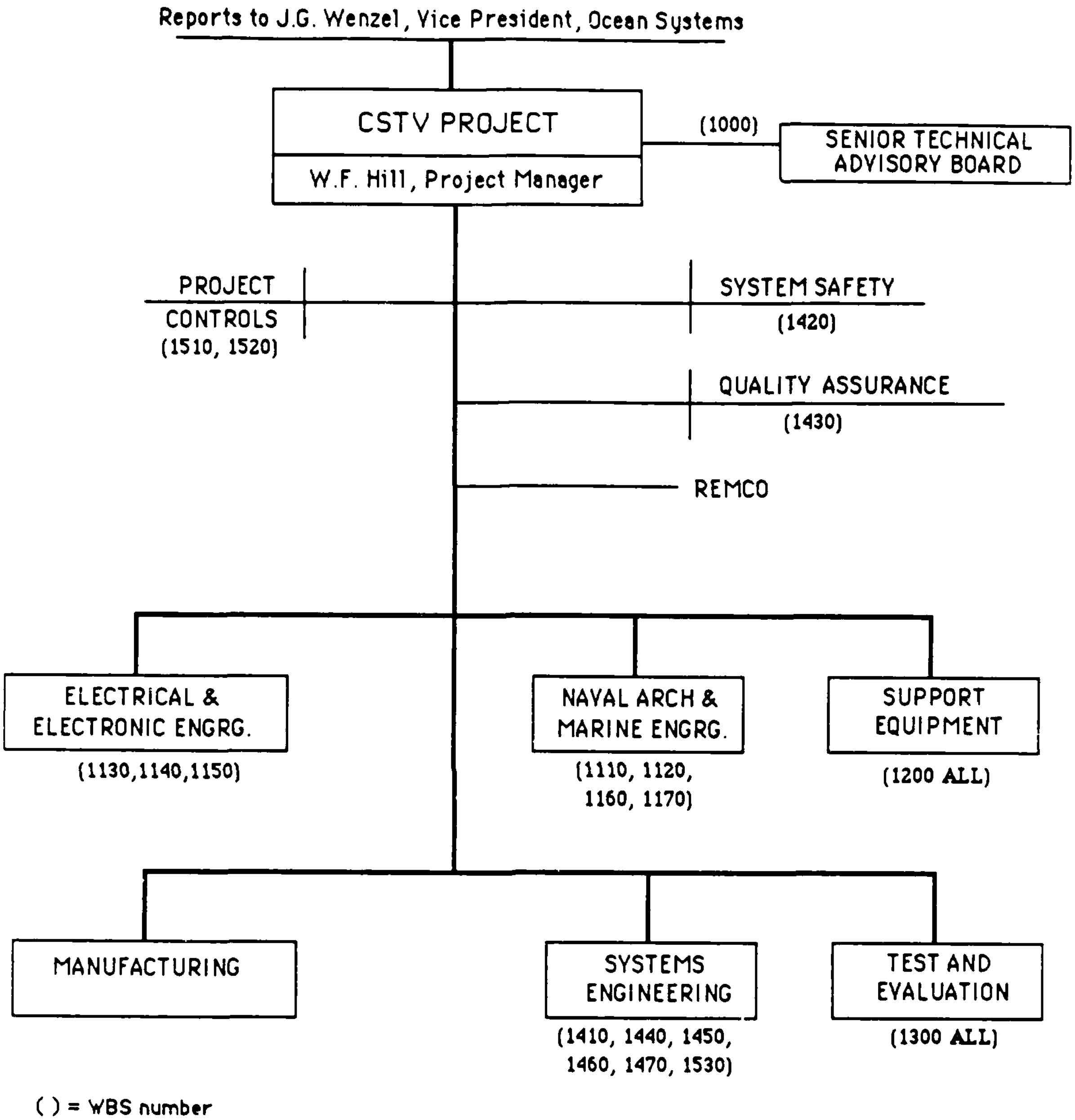

Figure 2. The CSTV Project structure and WBS task responsibilities

Source: LMSC Management proposal no. D085091 of 25 July 1978

hardware-oriented organization keyed to the Work Breakdown Structure (WBS). Major tasks and hardware elements are grouped based on similarity of content. Composed of key Ocean Systems engineers and Naval Architects, the Senior Technical Advisory Board, provided an important service for the CSTV project team. The board met quarterly and at the request of the CSTV project manager; to provide an independent audit and evaluation of technical and management progress. REMCO Hydraulics of Willets,California, the prime subcontractor was officially considered part of the CSTV project team. As developer of the CSTV's pressure hull, it was felt that close coordination and control of this most critical subassembly would best be achieved in this manner.

E. WORK BREAKDOWN STRUCTURE

A CSTV Work Breakdown Structure was used to control task definitions, work assignments, budget allocations, development costs, and the assignment of personnel responsibilities. It was seen as the master guide for identifying and evaluating all activities within the CSTV project. What follows is a description of the major elements of the WBS along with corresponding task identification numbers.

1100- MODEL (the Control System Test Vehicle itself). This element included all the technical analysis, design, fabrication, and procurement effort required to design, build, and deliver the complete CSTV vehicle incorporating both contractor furnished equipment (CFE) and government furnished equipment (GFE) items. Also included was the effort required to prepare and deliver the related disclosure information, drawings, and reports called for by the Contract Data Requirements List (CDRL). Subelements included: Hull and Appendages; Propulsion Subsystems; Power System; Control and Recording System; Navigation System; Auxiliary Systems; and Project Integration and Assembly. The work on the last task element was completed when the CSTV vehicle was ready for integrated systems tests.

1200- SUPPORT EQUIPMENT. This element included all technical analysis, design, fabrication, and procurement efforts required to design, build, and deliver the support equipment needed for the full operation of the CSTV System. The effort also included all documentation, reports, interface coordination, and liaison with the government and GFE suppliers. Subelements included: Control and Display System; Trailer; Sled; Dollies; Shipping Containers; Battery Chargers; Auxiliary Power System; and Miscellaneous Equipment.

1300- TEST AND EVALUATION. This element covered all efforts involved in planning and conducting required operational tests, including preparation of plans, actually conducting the test, the analysis of the results, and the preparation of the test reports as required by the CDRL. Subelements included: Development, System, and Acceptance Tests.

1400- SYSTEM ENGINEERING. Efforts under this element included those resources required to analyze and define the systems detailed requirements and the establishment and control of interfaces. It included defining and monitoring the integration of the vehicle, its support equipment, and all GFE components. Subelements included: Systems Engineering; System Safety; Quality Assurance, Reliability, and Maintainability Programs; Human Engineering; and Mockups.

1500- SYSTEMS MANAGEMENT. This element covered overall Project Management activities including technical and management direction, project controls, status evaluation, establishment of priorities, assignment of tasks, and other appropriate project management functions. Subelements included: Project Management; Configuration and Data Management; and Integrated Logistics Support.

Task elements of the WBS are assigned a unique charge number identified as a work order/work authority (WO/WA); which is also an element of the LMSC cost accounting system. This charge number corresponds to the WBS series and is further identified within

the accounting system in terms of organization number, primary cost element, and resource code. All budgeting, scheduling, cost collection, and measurement of work status begins at the cost account level. Thus the WBS is also the primary management control mechanism for summarizing various project information for reporting or monitoring purposes.

F. LMSC COST ESTIMATION SYSTEM

What follows is a description of the generic process used by LMSC to estimate the development and production costs of all projects, including those associated with technological extensions of the state-of-the-art. This process is the actual series of steps employed by the CSTV project team in estimating the project's development costs.The specific estimation method(s) used in the CSTV project along with any significant deviations from the generic LMSC process are examined in the following section.

The LMSC cost estimation process can be seen as a series of events, within phases, utilizing the various cost estimation techniques described in Chapter II in an effort to produce effective and creditable cost estimates. The primary considerations of the system are to:

* Ensure that source data for estimates are current, accurate, and complete
* Develop and maintain documentation in support of the estimates
* Assign responsibilities for originating, reviewing, and approving the estimates
* Utilize successful techniques for developing direct and indirect cost estimates

1. Pre-Proposal Planning

Figure 3 illustrates the key elements involved in the pre-proposal planning phase. The cost estimation process begins when a Program Manager is assigned to a new business activity. In the initial planning phase of a project, the Program Manager will form a combined Program Office Staff and a contract proposal team. This combined team is organized with clearly defined lines of communications and authority. The members of the proposal team consist of representatives from various functional divisions within the LMSC

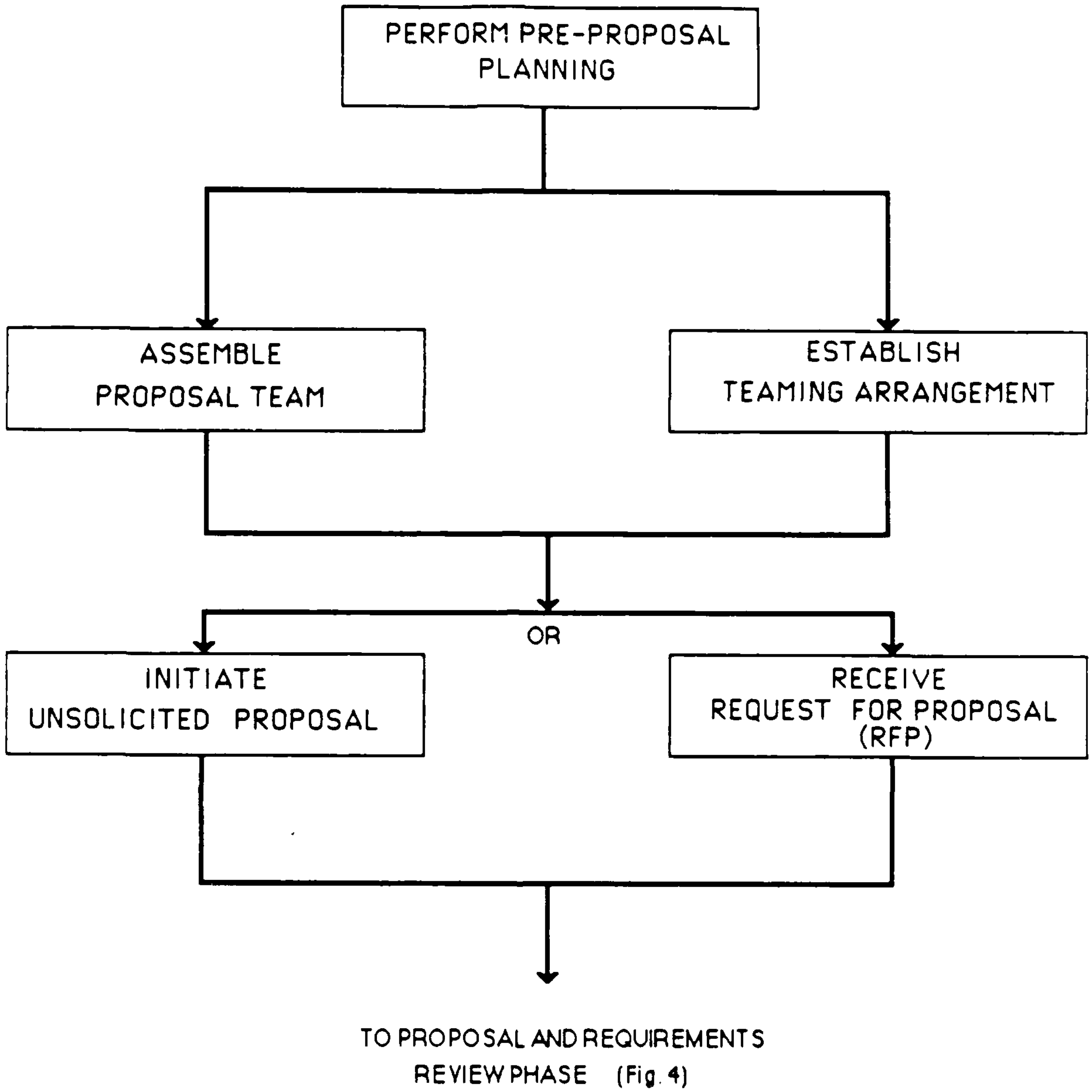

Figure 3. Pre-Proposal Planning

Source: LMSC Estimating System Description (ESD) Manual

organization who are believed to possess the specific skills and experience to plan the program and proposal efforts and to reliably estimate the projects' development and production costs. A teaming agreement [3] is authorized if : 1) the capabilities required are not available within LMSC, or 2) the unique capabilities of LMSC personnel coupled with non-LMSC team members are highly complementary and afford the customer the best combination of capabilities required to achieve system performance and cost objectives. The CSTV project did not require this arrangement as all capabilities were considered available within LMSC. Requests for Proposals (RFP) are used to communicate the government's requirements for a new contract. Once received, the proposal team begins the next phase of effort.

2. Proposal Requirements Review and Development

This phase of the estimation process involves a comprehensive review and interpretation of the technical and management requirements delineated in the RFP. Figure 4 is provided to include a complete presentation of the numerous events associated with this phase of the process. Only the most essential concerns will be discussed.

The first action, the Proposal Schedule, established the ground rules and future milestones that are to be incorporated in the overall cost proposal development and plan and schedule. An important objective of the proposal team is for cost proposals to identify the conditions and assumptions taken into consideration during its preparation. This is the focus of the RFP review process. Its intent is to single out those task elements or conditions that may impact highly on contract costs. The specific items of consideration include

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[3] A teaming agreement is a legally binding written agreement with another company (outside LMSC) to jointly prepare or conduct marketing research or development efforts leading to the award of a new contract.

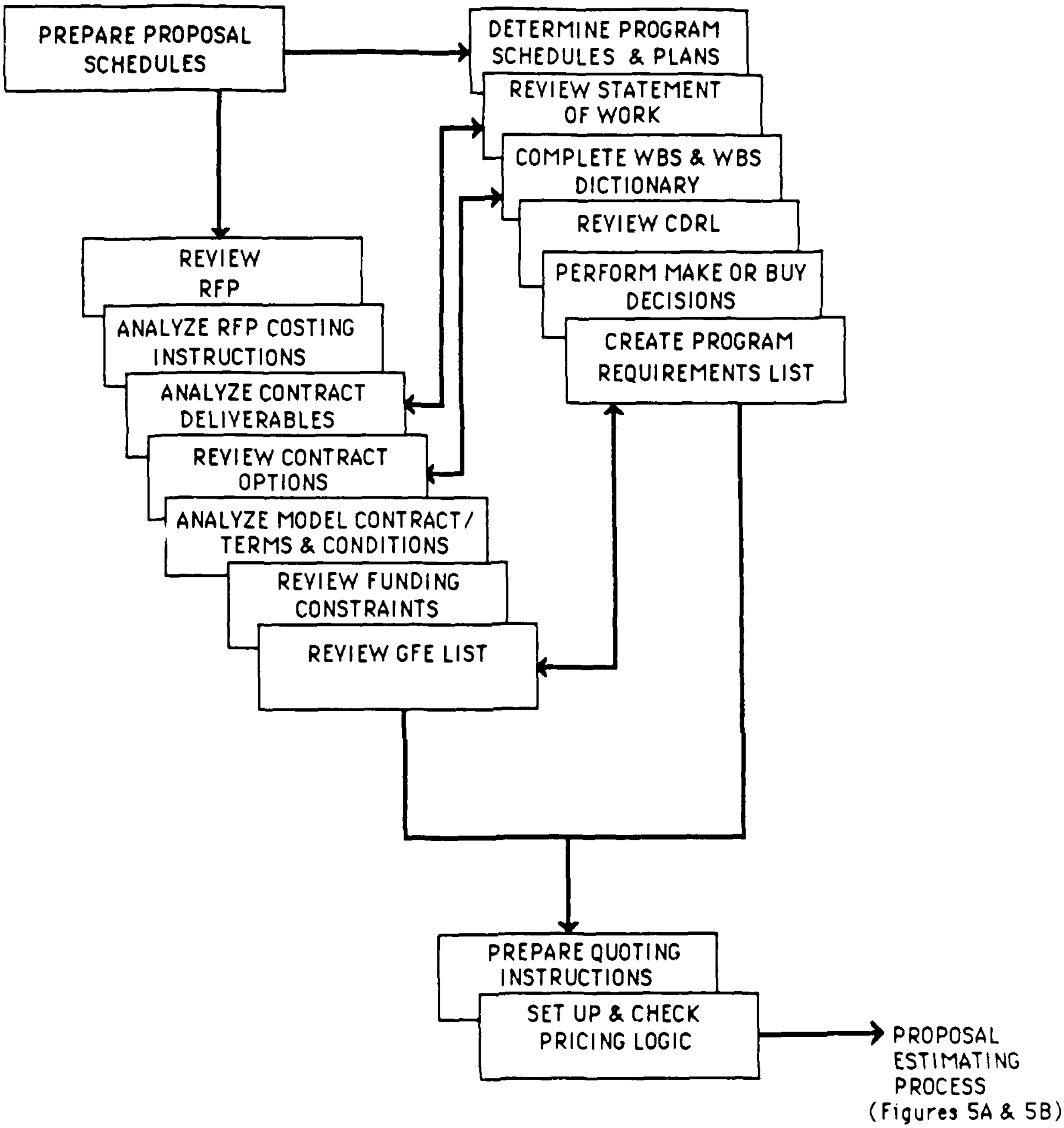

Figure 4. Proposal Requirements Review and Development Phase

Source: LMSC Estimating System Description (ESD) Manual

the: 1) review of contract deliverables, 2) examination of contract options,[4] 3) review of the terms and conditions, 4) review of any funding constraints, 5) review of the GFE list, 6) review SOW, WBS and WBS dictionary (task elements) and 7) review of CDRL requirements. Depending on project complexity, the degree to which technological methods will be required to be advanced, and the stringency or difficulty of the RFP requirements, additional levels of program scheduling and review may be conducted to define more detailed activities. If required, this phase would occur somewhat after (but in some cases parallel to) the review phase. As part of the program scheduling and planning task, a make-or-buy analysis is also conducted. Often this is a formal requirement stated in the RFP. The CSTV project however, did not require this documentation, presumably because it was considered a development project involving no follow-on production.

One of the most important LMSC documents resulting from this phase is the Program Requirements List (PRL). This list contains all equipment, subcontracts, and software needed for pricing. Also often included with the PRL is descriptive data on all listed items. These are known as fact sheets, and are put together by engineering divisions and are used in "bottom-up" cost estimation.The final two steps within this phase of the estimation process involve issuing quoting instructions and defining pricing logic ground rules. These instructions are intended to produce consistency and prevent confusion during the next phase of the process; the proposal estimation process.

3. Proposal Estimation

This section describes the LMSC process for determining and developing valid cost rationale and estimation. Figures 5A include all of the major steps involved in this

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[4] A contract option is a unilateral right in a contract by which, for a specific time, the government may elect to purchase additional supplies and services called for in the contract, or may elect to extend the terms of the contract.

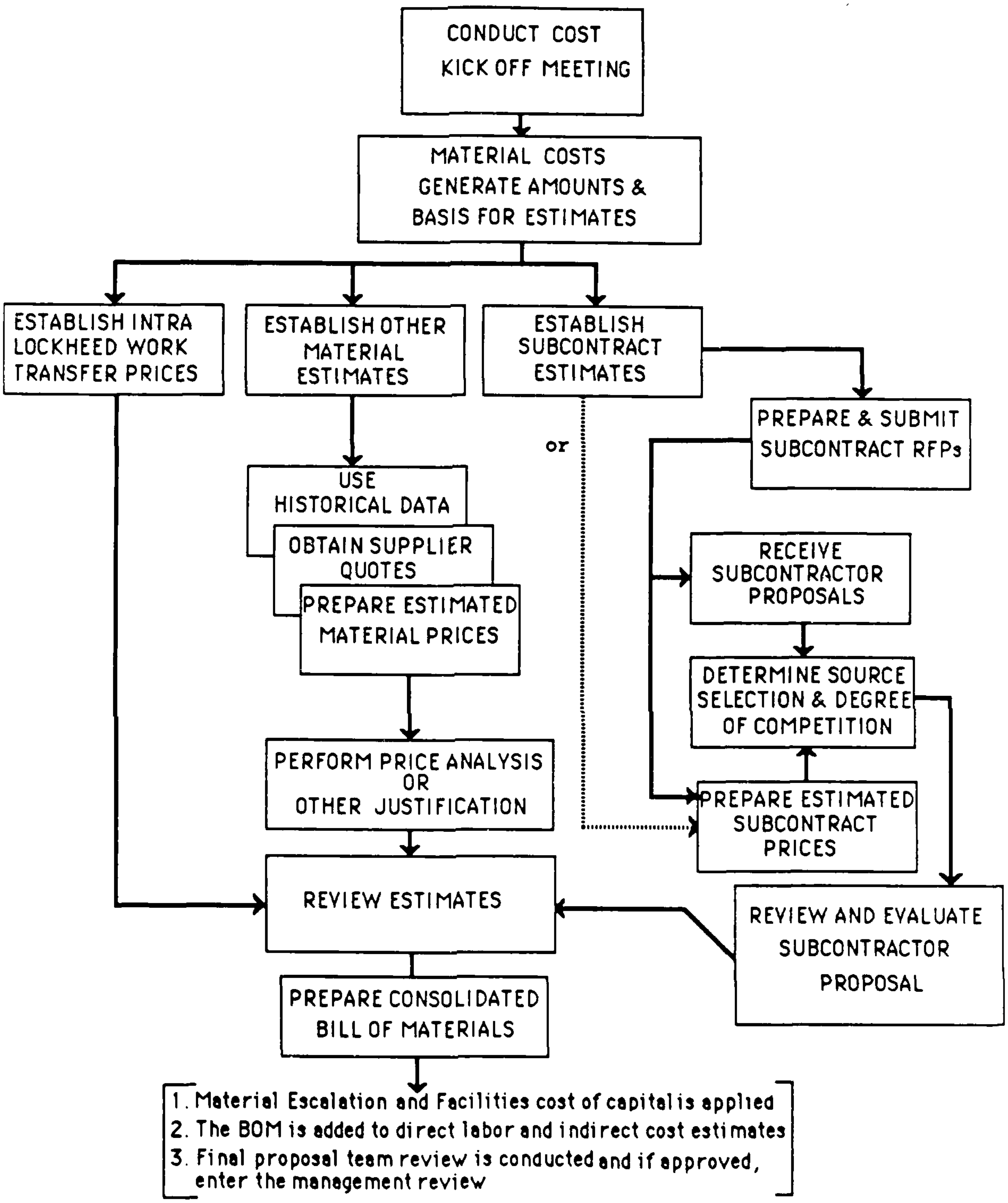

Figure 5A. Proposal Estimating Process Phase
(Direct Materials)

Source: LMSC Estimating System Description (ESD) Manual

phase. For the purposes of this paper, only those steps used by the CSTV project team and any other essential steps will be reviewed. It is also worth mentioning here that a significant number of the steps involved in the LMSC estimation process are designed to satisfy the voluminous documentation requirements established by the Federal Acquisition Regulations (FAR) as opposed to generating pure estimations of development and production cost of a particular project. Documentation requirements of the Federal Acquisition Regulations are beyond the scope of this study. Therefore, the process involved will be described in terms of the steps whose objectives are solely that of estimating development and production costs.

This phase in the process begins with a "kick-off" meeting where cost input scheduling, cost/price estimating procedures, and other administrative preliminaries are established by the program manager. Once these ground rules are established, the actual cost estimation work begins.

The total cost estimate is composed of three major cost categories. These are: direct materials (and its corresponding overhead costs), direct labor (and its corresponding overhead costs), and other direct costs. The material costs are further broken down into three categories and involve the following actions:

A. Subcontracted material and purchased services: This category includes project specific parts, components, reworked items and test, and consulting services that are not to be manufactured or provided directly by Lockheed itself. The solicitation of various subcontractors is done via formal Lockheed RFP's or informal request for quotations (RFQ). Often there is insufficient time to obtain subcontractor cost data before the Lockheed proposal due date. Moreover, as is the case with state-of-the-art developments, subcontractor supplied materials and the corresponding price quotations are not available. In this case, Lockheed will prepare an in-house

estimate based on a quote for similar effort from another subcontractor (analogy or similar-to method), or purchase order history from a similar contract (bottom-up method).

B. Standard commercial material and raw material: This category includes standard items that Lockheed normally fabricates, in whole or in part, and that are generally stocked in inventory. Raw material consists of material in a form that requires further processing. Supplier quotations are the preferred method of obtaining cost data however, often as is the case with state-of-the-art developments, in house estimation is again utilized.

C. Intra-Lockheed work transfer (IWT): This category includes all material items that are fabricated by Lockheed itself. The raw materials for these items are carried in Lockheed inventory and hence are accounted for at actual costs. No material estimation is therefore needed.

An important step prior to the forwarding of a final consolidated Bill of Material (BOM) is a process called Price Analysis. This auxiliary analysis is performed whenever (1) the total BOM amount exceeds $100,000 and/or (2) the rate of technological change of the project is believed to include significant uncertainty as to justify additional review and consideration of the reasonableness of the cost estimation. The specific actions taken in conducting a Price Analysis, including the following:

* Comparison of price quotation received
* Comparison of prior price quotations with current current quotations for the same or similar end items
* Employing parametric modeling techniques as "sanity" checks, i.e. do these prices appear reasonable?
* Comparing prices set forth in published price lists with discount or quantity buy opportunities
* Comparison of proposed prices with independently developed Lockheed estimates (similar-to method)

The end product of the material cost estimation process described above is a consolidated Bill of Material (BOM) composed of the individual cost categories. Final action on the BOM involves the application of a material escalation rate depending on the anticipated length of the particular project.

The next category of cost to be considered is that of direct labor. Figure 5B illustrates the steps involved in this phase of the process.The estimates associated with direct labor are prepared and expressed in labor hours traceable to the research, design, development, and production of a particular project. Labor hour requirements for completion of the work to be performed as outlined in the statement of work (SOW) or work breakdown structure (WBS) are estimated. There are two basic methods used to arrive at these labor hour estimates.They are : (1) the Similar-To or Analog method; or (2) the Engineering or "Bottom-Up" method. The Similar -To method is the preferred technique. It generally yields the most accurate estimate if properly executed. However, this method requires the availability of extensive historical data upon which to base the estimate. The CSTV project along with many state-of-the-art extension projects may involve a significant number of tasks in which little or no similar data exists. Therefore, the Engineering method is generally used to estimate the labor costs associated with state-of-the-art extension projects. The CSTV project involved the utilization of both methods, however much of the labor estimation was based upon engineering estimates. Once direct labor hours are estimated, they are converted to dollar costs by means of applying (1) cost standards; and (if appropriate) (2) learning curve theory. The cost standards are based on relating development and production costs to the specific characteristics of the project (such as composition, weight, size, or duration) and applying Lockheed and/or industry-wide statistics as appropriate. In general, learning curve theory states that the amount of time required to complete a given task will diminish over time as workers gain added experience

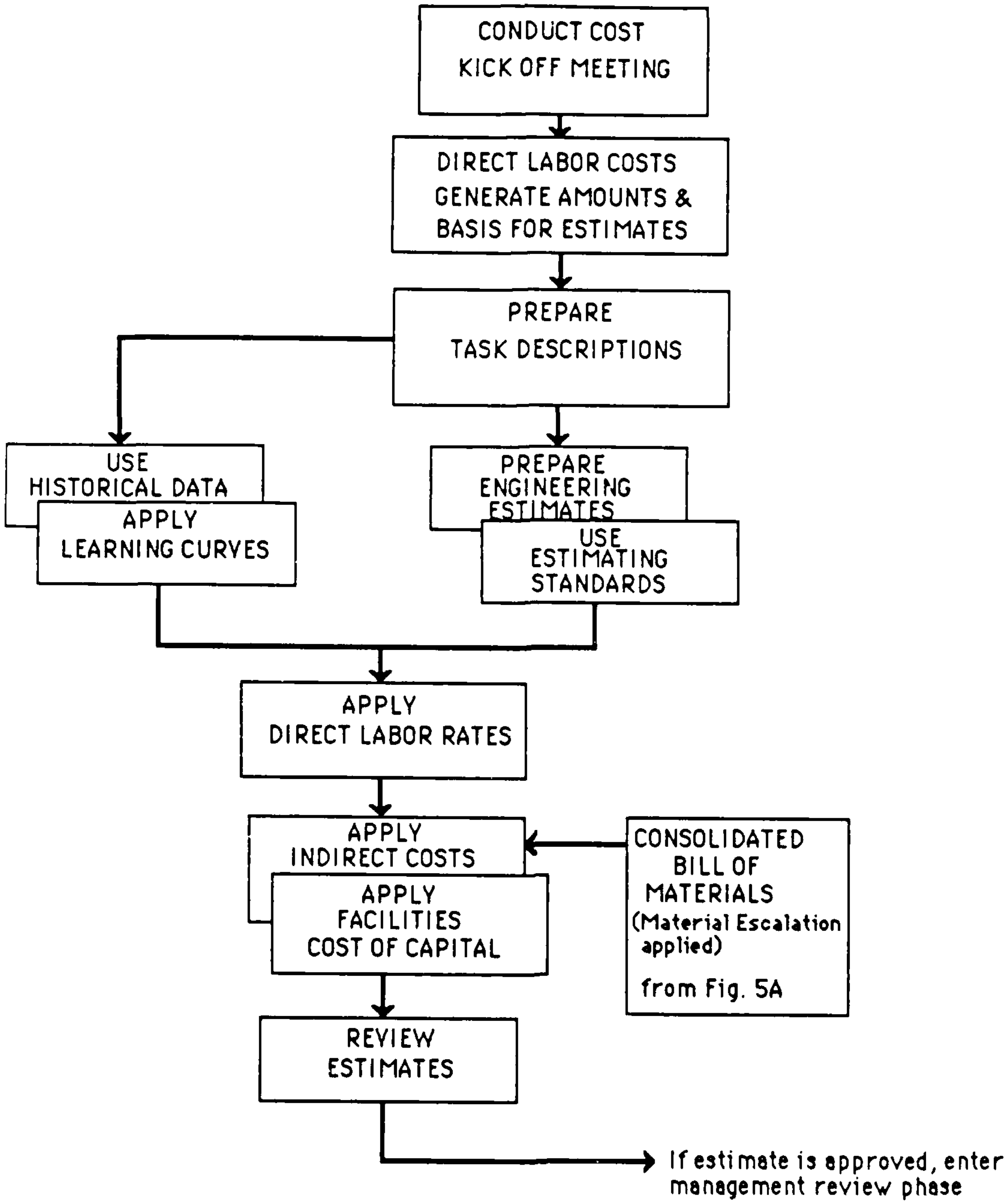

Figure 5B. Proposal Estimating Process Phase
(Direct Labor and Other Direct Costs)

Source: LMSC Estimating System Description (ESD) Manual

performing a given task. LMSC obtains the specific rate of learning for each labor task by employing the least-squares method of curve fitting to a LMSC specific labor cost database. Although learning curves may be correctly applied to some projects involving state-of-the-art extensions, the CSTV project did not include the application of a learning curve rate. This was apparently due to the unique nature of the project and the fact that no follow-on production was required.

The final category of cost estimated is that associated with travel, overtime premiums, and other direct costs not previously included. Typically these costs are arrived at by similar-to techniques or direct quotations from supplying sources. The final phase of the LMSC cost estimating system involves a process of extensive management reviewoutside the auspices of the project team. Post-estimation phase techniques and considerations are the subject of the following section.

G. OTHER CONSIDERATIONS AND COST MODELING

A series of management reviews are conducted prior to the final proposal and following the approved cost estimates developed during the proposal estimating process. LMSC utilizes a parametric cost model; the RCA PRICE (Hardware) model, and a combined analogy/associated model; the Lockheed STAR model. Discussion in this section is not meant to imply that their use is reserved solely for the later phases of the estimation process. These methods are used to provide credibility or "sanity" checks throughout the <u>entire</u> acquisition process. This concept is illustrated in Figure 6.

As can be seen, the "mix" of cost estimation techniques utilized by LMSC is time phased and correlated with the project managers view of cost uncertainty. What follows is a brief presentation of the two methods used by LMSC to provide for creditability checks throughout the cost estimation process.

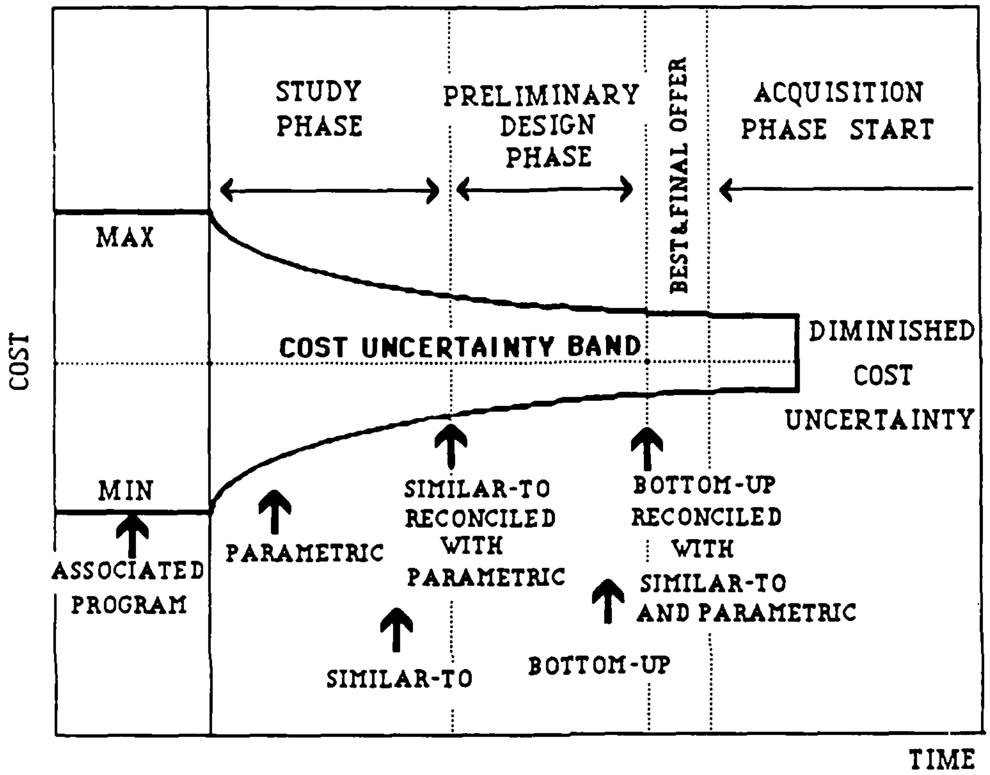

Figure 6: The use of various cost estimation techniques throughout the acquisition process

Source: Information received during interview with LMSC Etimating Systems Manager, Mr. T. Castro on 24 September 1987.

1. RCA PRICE (Hardware) Model

The parametric model known as the RCA PRICE (Hardware) model is a commercially available decision support system that is appropriate for estimating development and/or production costs at the subassembly or higher level. It is not appropriate for use with extremely small component parts. Input into the model is achieved by means of microcomputer with direct access through data link (MODEM) to the RCA PRICE mainframe computer. Input parameters include:

(1) Physical factors: component weight in two domains; (a) the active electronic weight and (b) the mechanical/structural weight. These two input variables are considered critical to the accuracy of the RCA PRICE output. Additional physical factors include the volume and/or density of the component. These two inputs are not as critical to output accuracy.

(2) Qualitative inputs: component empirical data in three variables; (a) the electronic complexity, (b) the structural/mechanical complexity, and (c) the engineering complexity. The critical variable for developmental projects is the engineering complexity input; which pertains to the scope of hardware development task and the skills of the project team. Values for these quantitative factors are provided in matrix form by the model.

(3) Other inputs: These parameters incorporate idea such as design repetition, number of prototypes to be developed, end units to be produced, production learning curves, and economic factors for escalation/de-escalation of labor rates.

Input variables are completed for all identifiable hardware items of the system and are entered into the RCA PRICE model. The cost output received by the model is broken down into hardware development, production, and total costs. Input parameters are repeated and "what if" analysis is easily accomplished and thus cost categories that significantly affect total costs, i.e. cost drivers, can be identified. Several limitations of the RCA PRICE model are apparent. The most obvious is that input parameters require that system characteristics be known *a priori* to the estimate. This severely limits its application to state-of-the-art extension projects in that many of the characteristics are unknown or at best subjective estimates themselves. The accuracy of the output is also highly dependent on the

input parameters. In addition, the actual algorithm employed is considered proprietary in nature and thus is not easily validated. One would expect to find significant skepticism associated with this method of estimation. However, interviews with LMSC cost estimators conducted by the researcher revealed surprising support and credibility for the model.

2. Lockheed STAR Model

The Lockheed STAR cost estimation model is a combination of the characteristics inherent in both the associated and the similar-to models. The primary focus in the STAR model is the extensive use of detailed databases drawn from a large number of past Lockheed projects over a twenty year period. Three separate and distinct databases are maintained and used to generate cost estimates. Depending on the project under consideration, the Flight Hardware, Ground Hardware, or Software databases are accessed to cost data pertaining to a particular element or task being costed. The estimation model matches the task and project of interest to functionally analogous programs and historical cost experiences found within the database. Each model (Flight Hardware, Ground Hardware, or Software) uses an algorithm tailored to its own specific application and reflects the way in which Lockheed does business. If required, all three application programs can be integrated to produce a total system cost estimate. The STAR model databases do not include ocean systems project experience and hence was not utilized in the CSTV project. However, it is included in the discussion due to its extensive current use by LMSC cost estimators.

H. SUMMARY OF THE COST ESTIMATION PROCESS USED FOR THE CSTV PROJECT

The CSTV project closely followed the LMSC estimating system process previously discussed. What is now discussed is the estimating methods utilized in developing the CSTV project cost proposal. The predominant method used by LMSC to estimate the development costs for the CSTV contract proposals was the engineering or bottom-up

technique. Past experience with costs associated with similar projects was relied upon when comparisons were considered appropriate [5]. Often, however, the advanced technical nature of the CSTV project prevented direct applications and various adjustments were made in an attempt to improve estimation validity.

LMSC's cost proposal for the Cost-Plus Fixed Fee (CPFF) contract used in support of the CSTV acquisition contained the following explanations of the development costs included and how these costs were derived:

1. Direct Materials: The material requirements for the project were directly estimated based upon the Work Breakdown Structure (WBS) and the Statement of Work (SOW) documents. The costs were based on vendor quotes, catalog prices, previous purchase order history, and bottom-up engineering estimates. Common minor materials (standard or common productive parts having broad applicability and wide usage) were applied to direct materials by a negotiated fixed government rate.This rate is a LMSC standard rate based on historical costs.

2. Material Overhead: This cost element represented the administrative burden associated with material and subcontract costs in two categories; material and procurement. Prenegotiated fixed rates based on historical costs were applied to each item.

3. Direct Labor: The estimated direct labor hour requirements for the CSTV project were derived from engineering estimates made by project team members.Task requirements were identified by analysis of the CSTV project WBS. Labor classifications were made as follows: Staff Engineers, Specialized Engineers, General Engineers, Inspection, Technical Publications, and Manufacturing Development. Hourly labor rates, provided by LMSC's company-wide pooled labor rate database system, are applied to each labor classification total. These rates were incrementally escalated by cost of living/merit increase factors expected to be incurred.

4. Labor Overhead: Labor overhead costs are divided into two categories; development overhead and manufacturing overhead. Specific rates were applied to the labor hour estimates of each category. These rates are company-wide, pre-negotiated and based upon historical LMSC cost experience.

5. Travel Costs: Direct travel costs are based on the number, destination, and duration of trips expected to be required to satisfy the requirements for testing and special material item procurement. LMSC standard costs, based on tourist class, round trip airfares and government approved per diem rates, were used.

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[5] These similar experiences in which the CSTV project team referred to included the Deep Submergence Rescue Vehicle (DSRV), the Summa Ocean Mining Barge, and the Deep Quest Research Submersible projects.

6. Other Direct Costs: This category included four classifications to include reproduction, computer, facility capital cost of money, and overtime premium costs. Reproduction included labor, materials, and vendor support costs associated with the process of reproducing technical drawings, project plans, and blueprints. The rate per hour applied to total labor hours was a negotiated amount based on historical LMSC reproduction experience. Computer Assisted Design and Manufacturing (CADAM) techniques were used to produce 160 technical drawings. Structural stress and moments of inertia analysis was accomplished using a UNIVAC 1110 computer. The estimated computer time for these tasks were based on engineering estimates. The applied rates per computer hour were negotiated and based upon historical LMSC data processing cost experience. Facilities Capital Cost of Money (FCCM) was applied to direct labor hour estimates at a negotiated rates for all categories of indirect costs. The CSTV project team felt that unscheduled overtime would undoubtably occur as development and test functions were consciously extended and completed beyond an eight hour shift. Overtime premium costs associated with this likelihood was composed of two parts; estimated overtime hours and a negotiated rate to be applied to these hours. The primary basis for the estimated overtime hours was the LMSC experience in association with a similar past project combined with the estimates of project members.
7. General and Administrative Expense: A G&A expense rate was applied to the CSTV project's total estimated labor hours. This negotiated rate was based on historical LMSC experience.

I. CHAPTER SUMMARY

This chapter began with a system description of the Control System Test Vehicle project. Contractor responsibilities and task requirements were outlined and discussed in terms of the Statement of Work and the Work Breakdown Structure documents. Various organizational aspects of Lockheed, LMSC, and the CSTV project were seen as assimilating management policies and the project team structure of technical undertakings successfully accomplished previously within the Lockheed Corporation. The complex and comprehensive LMSC cost estimating system and the techniques utilized were presented from the perspective of generating valid and accurate cost estimates. The concept of time phased cost estimates and "sanity" checks provided the reader with insights into how various cost estimation techniques are applied throughout the development process. The final section of this chapter points out significant techniques and considerations used in the development of cost estimates for the CSTV project.

IV. PRESENTATION AND ANALYSIS OF THE DATA

A. INTRODUCTION

The preceding chapter introduced the process and techniques by which LMSC generates cost estimates for its state-of-the-art extension projects. This process was followed by the CSTV project team with very few exceptions. The purpose of this chapter is to present and analyze the results of the LMSC cost estimation process of the CSTV project. First, the original CSTV project cost estimate and the results of the Best and Final Offer contracting process are compared. The rationale for the revised cost estimates is then presented. Next, a presentation and analysis of the predicted and the actual development costs experienced is conducted. This data is presented in chronological order as was experienced throughout the life of the project and includes justifications for cost growth and variances amounts. Conclusions are then reached concerning the principle factor(s) which significantly impacted CSTV project costs.

B. INITIAL CSTV PROJECT COST ESTIMATES

Appendix B contains the Contract Pricing Proposal (DD form 633-4) dated July 21, 1978. This document is the result of the initial cost estimation effort on the part of the CSTV project team. As part of normal contracting procedures, a negotiation process between representatives of LMSC and the government followed submission of the Contract Pricing Proposal. What resulted was a "Best and Final Offer" (BAFO) proposal submitted by LMSC on October 20, 1978. Appendix C contains the Contract Pricing Proposal (DD Form 633-4 dated October 18, 1978) which was provided as an enclosure to the BAFO submission. As is evident upon comparison of these two documents, the total estimated

project cost was reduced by a substantial sum [6] . It is important to realize that some of the difference in estimated project cost was due to changes in contract requirements as requested by the government. The following summary shows how the total contract values changed as a result of this negotiation phase.

PRIOR TO BEST AND FINAL OFFER:		
Initial estimated cost	$ 2,276,503	
Fixed fee		191,862
Total CPFF contract amount		$ 2,468,365
AFTER BEST AND FINAL OFFER:		
Initial estimated cost	$ 1,659,545	
Fixed fee		114,857
Total CPFF contract amount		$ 1,774,402
DIFFERENCE:		$ (693,963)
PERCENTAGE REDUCTION:	(39.11%)	

There were several reasons for the reduction in estimated project costs; and are provided as follows.

1. Direct Materials

Materials and subcontracted items were reduced by $313,050 as a result of :

(a) A change in the prime subcontractor responsible for manufacturing the pressure hull. This change (from REMCO to Niles Engineering) resulted in a significant price reduction.

(b) An increase in government furnished items (GFI) as a result of negotiated contract changes.

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[6] The BAFO figures, as will be seen, were not the final negotiated amounts. They are presented here to provide a complete accounting of the changes in cost estimates which occurred throughout the project.

(c) Market research into sources of continued suppliers allowed for substitution of lower per unit cost components.

2. Direct Labor

As a result of reevaluating the engineering process, estimated engineering labor requirements were reduced by 2,470 hours. Small economies and design improvements were effected to reduce the projected number of assembly drawings required. An additional 833 labor hours of test engineering efforts were eliminated for being"non-essential" in nature. Total direct labor dollars were reduced from $ 524,743 to $434,850; a difference of $89,893.

3. Manufacturing

Manufacturing labor estimates were reduced by 4,673 hours. This was due to numerous changes in the basic development contract. Because these changes were brought on by the government, for the purpose of this study , they are considered "contract reductions " and should not be treated as true cost variances or overruns.

4. Computer Time and Reproduction

The expected project computer time was reduced by 992 hours; from $63,414 to $33,654, a difference of $29,760. This was a direct result of the revaluation of the engineering process and corresponding reduction in the number of projected assembly drawings required. The expected reproduction expense was also reduced by $1,220 for the above cited reasons.

C. CSTV PROJECT COST GROWTH AND VARIANCE ANALYSIS

As a result of further contract negotiations after LMSC submitted it's BAFO, an estimated project cost of $1,682,819, and a fee or profit of $116,566 was agreed upon. A CPFF contract was signed on 29 December 1978 and work on the CSTV project began soon afterwards.

Despite the thorough pre-contract award estimation efforts expended, a myriad of technical and scheduling difficulties were experienced throughout the development of the CSTV project. The initial estimated cost figure of $1,682,819 and the scheduled project completion time was formally changed a total of six times between August 24, 1979 and February 12, 1981. A combination of contract modifications and cost variances resulted in a final actual project cost of $3,979,838. The final completion date of the CSTV project was March 30, 1982; more than two years beyond the initial January 1980 target completion date. All cost figures are nominal amounts measured in then-year dollars. This along with subsequent data was obtained by examination of LMSC documentation generated as a consequence of actual cost growth and overruns experienced throughout the life of the project. The negotiation/approval process associated with Cost Plus Fixed Fee (CPFF) contractual agreements, necessitated the format of the reports from which the researcher compiled the data. Accumulated costs are presented to the government for acceptance. The basis for these changes in estimated costs are justified by contract modifications and expected cost variances (expected because LMSC cannot incur additional costs prior to government review and approval) [7] . Thus a periodic negotiation process ensues between the government and LMSC with allowable costs resulting.

Much of the data reviewed provided information on both costs and fee (profit). The objectives of the study limits its relevance to analysis of cost data exclusively. The following table provides a chronological summary of the cost estimation changes actually experienced throughout the life of the CSTV project.

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[7] Actual cumulative costs form the basis for the total estimated project cost and is compared to the cumulative approved costs to determine the expected variance amount. See Appendix D.

TABLE III

FINAL NEGOTIATED CONTRACT GROWTH & VARIANCE RESULTS

DATE	ACTION	MODIFICATION	VARIANCE	TOTAL
29 Dec 78	Start Date	N/A	N/A	
24 Aug 79	Analysis #1	82,925	524,798	607,723
12 Nov 79	Analysis #2	192,986	375,773	568,759
29 Feb 80	Analysis #3	128,876	345,014	473,890
24 Jun 80	Analysis #4	239,817	209,970	449,787
29 Aug 80	Analysis #5	0	90,510	90,510
10 Dec 80	Modification*	75,000	0	75,000
12 Feb 81	Analysis #6	0	31,350	31,350
30 Mar 87	Completion	$719,604	$1,577,415	$2,297,019

* On this date, it was agreed upon to modify the contract by decreasing the fee by $75,000 and increasing the cost by the same amount.

Detailed data (by the above actual reporting dates) concerning CSTV project cost growth and variance is provided in Appendix D and support all the data presented in the following pages. Reasons for these difference are worthy of examination so that insights into the risks, uncertainties, and technical difficulties associated with this particular state-of-the-art extension project may be made. Contract modifications as requested by the government will be identified but not be discussed in length as these estimated costs were developed by means of the LMSC cost estimation process and models previously discussed. Insights into the reasons for the cost variances will be the overriding objective.The primary rationale for each revisions of the cost estimate will now be discussed in the order in which they occurred throughout the life of the CSTV project.

1. CSTV Cost Growth and Variance Analysis Number One

The first formal change in the CSTV cost estimate occurred on August 24, 1979. The cost revision as of this date is summarized as follows:

	Cost
Basic Contract	$1,682,819
Contract Modifications	82,925
Variance or Cost Overrun	524,798
Revised Estimated Cost	$2,290,542
Estimated Project Completion Date	May 1980

The contract was modified at the governments request to include 1) the design and manufacture of a special boom assembly , 2) the procurement/design of special filters, and 3) an increase in the accuracy of a specific subsystem. The primary reason for the variance experienced as of this date was directly contributable to the complexity and sophistication of the CSTV itself. In 197~ LMSC was awarded a preliminary design contract. Design studies then began in anticipation of a Navy RFP. Because of the extensive preliminary design work completed prior to the RFP, it was the opinion of LMSC that very little preliminary design would be required at the time that the contract would be let. As a consequence, the LMSC Best and Final Offer reflected only a minor amount of anticipated preliminary design costs. However, it soon became apparent that Navy specifications, especially those dealing with the tail section design and other technical matters, were not being precisely meet with the design efforts to date. Further preliminary design work was needed. Further problems surfaced once actual developmental work began. The complexity of the project required additional drawings (from 136 to 321) and engineering effort in order to adequately define the product. In addition, a number of procurement difficulties were experienced. The most significant being the rejection of unsatisfactory hull material from Kaiser Aluminum. Reprocurement of this material amounted to project delays and

fruitless efforts at obtaining an alternate source of supply. Finally, significant quantities of highly specialized precision components, required by the CSTV, were fabricated by LMSC when they proved to be unavailable "off-the-shelf" as had been previously expected. In summary, the following factors contributed to the cost variance at this stage of project development:

(a) Substantially more preliminary design effort than anticipated.
(b) Significant procurement difficulties experienced.
(c) Off-the-shelf components not available to the extent planned.

2. CSTV Cost Growth and Variance Analysis Number Two

The second formal change in the CSTV cost estimate occurred on November 12, 1979. The cost revision as of this date is summarized as follows:

	Cost
Allowable Costs to Date	$2,341,255
Contract Modifications	192,986
Variance or Cost Overrun	375,773
Revised Estimated Cost	$2,910,014
Estimated Project Completion Date	May 1980

The contract was modified at the governments request to include 1) further efforts to design test and manufacture an additional tail section for the CSTV and 2) an upgraded electronics package. Since the first cost growth and variance analysis, a number of technical and schedule problems developed which directly impacted the estimated project completion costs as seen above. The first problem had to do with CSTV hull fabrication difficulties experienced at Niles Machine Inc., the prime subcontractor. The time to complete welding of inserts, closures, and foundations was greater than anticipated. Significant numbers of LMSC technicians were sent to the subcontractor site in an attempt to rectify the holdups. In the end it became necessary to transfer entire sections of the hull to LMSC for completion of welding work. Problems with the control electronics and procurement of a

critical ballast pump assembly was the second difficulty encountered by LMSC at this time. Electrical wiring changes were necessary after initial hull sections were received and found to be more densely packed than anticipated. Finally the overall complexity and cumulative design changes thus far in the project resulted in additional quality assurance, rework, and continued engineering design efforts. In summary, the following factors contributed directly to the continued variances in development costs:

(a) Hull fabrication difficulties.
(b) Procurement difficulties experienced with major subassemblies.
(c) Technical problems associated with wiring configuration greater than anticipated.
(d) Additional design work Q/A, and rework beyond expectations.

3. CSTV Variance Analysis Number Three

The third formal change in the CSTV cost estimate occurred on February 29, 1980. The cost revision as of this date is summarized as follows:

	Cost
Allowable Costs to Date	$2, 859,301
Contract Modifications	128,876
Variance or Cost Overrun	345,014
Revised Estimated Cost	$3,333,191
Estimated Project Completion Date	September 1980

No additional contract modifications were identified as of this reporting date. However, a significant cost variance was experienced. Additionally, the CSTV project incurred its first estimated program schedule extension. LMSC was experiencing several unanticipated procurement and subcontractor performance difficulties. Delays in manufacturing critical path items, such as the sail and tail subassemblies, were traced to the lack of required component parts. These events not only resulted in project delays but caused LMSC to expend considerable efforts in resolving these problems. Cost overruns not directly linked to project delays due to lack of components, primarily included continued

difficulties with hull fabrication and unexpected hardware integration problems between off-the-shelf components (also of which required custom-made connector parts). This situation required the addition of more engineering and administrative man-hours than expected. Planned expenditures for material costs were not significant affected. A summary of the primary reasons for the increased development costs estimate include:

(a) Delays associated with deliveries of component parts; some of which directly affect tasks on the critical path.

(b) Difficulties with connections between components

(c) Continued problems with hull fabrication

4. CSTV Cost Growth and Variance Analysis Number Four

The fourth formal change in the CSTV cost estimate occurred on June 24, 1980. The cost revision as of this date is summarized as follows:

	Cost
Allowable Costs to Date	$3,333,191
Contract Modifications	239,817
Variance or Cost Overrun	209,970
Revised Estimated Cost	$3,782,978
Estimated Project Completion Date	February 1981

The contract was further modified at the government's request to include 1) a second tail assembly, and 2) a modification to the existing installed tape recording system. The cost variances experienced at this time primarily resulted from continuing problems remaining as of the last report date. These difficulties were expected to be resolved relatively quickly. As it turned out however, LMSC was unable to accomplish this without utilizing significant additional resources. The cost overrun was primarily attributed to continuous subcontractor difficulties which required additional LMSC personnel being sent to the subcontractor's sites in an attempt to rectify component design and manufacturing problems.

5. CSTV Variance Analysis Number Five

The fifth formal change in the CSTV cost estimate occurred on August 29,1980. The cost revision as of this date is summarized as follows:

	Cost
Allowable Costs to Date	$3,782,978
Variance or Cost Overrun	90,510
Revised Estimated Cost	$3,873,488
Estimated Project Completion Date	January 1981

No additional requests for contract modifications was reported at the time of this cost analysis report. In fact, most of the problems experienced earlier seemed to be resolved. The variance, as verified above, was the smallest anticipated thus far in the CSTV project life. However, a relatively new technical difficulty surfaced which caused the continued high usage of certain engineering and manufacturing personnel. This involved repair, modification, and isolated testing of key components of the CSTV control mechanism. As will be seen, this problem was not completely resolved prior to the submission of the final variance report.

6. CSTV Variance Analysis Number Six

The final formal change in the CSTV cost estimate occurred on February 12,1981. The cost revision as of this date is summarized as follows:

	Cost
Allowable Costs to Date	$3,948,488 *
Variance or Cost Overrun	31,350
Revised Estimated Cost	$3,979,838 (Final Cost)
Actual Project Completion Date	March 1981

* On 10 Dec. 80, it was agreed upon to further modify the contract by increasing allowable project costs by $75,000.

No further government induced contract modifications were experienced through the completion of the CSTV project. The anticipated variance was attributed to remaining

technical problems associated with the CSTV control system. In addition, the costs for the second tail assembly and computer graphics time for final drawings were greater than expected.

The objective of the preceding paragraphs was to present the estimated and actual cost data in a format that would be easily comprehended by the reader. Furthermore, the reasons for the increase in project costs were provided so as to identify the various factors impacting on cost. As is apparent by observing the differences between the beginning cost estimate and the actual project cost results, these differences are significant. Even with a process as complete and exhaustively detailed as the LMSC approach, the process of cost estimation in this particular case was an exceedingly challenging one.

In the opinion of the researcher, the value of a model such as the LMSC estimating system stems not only from its capacity to accurately predict future costs but also in its ability to enhance the identification of factors influencing it's outcome. It was shown that the total difference is a combination of the CSTV project's cost growth and cost variance or overruns. It would appear that several factors throughout the development of the CSTV project contributed significantly to increases in actual cost. The degree of technological extension required would be expected to directly affect development cost by increasing uncertainty associated with various task accomplishment. The CSTV project costs appeared to be adversely affected by this task uncertainty. In fact, by observing the data contained in Table III, it is interesting to note that variance amounts appear to be greatest in the initial stages of project development. Moreover, these amounts decrease with the life of the project and presumably with a reduction in task uncertainty. It was seen that extensive difficulties were initially experienced and that extended preliminary design work was required. The uncertainty factor seemed to shift away from LMSC personnel and more towards subcontractors. As was observed, the major reason for cost overruns in the later

stages of development appeared to be design and manufacturing difficulty with subcontractors. Numerous LMSC technical visits were conducted to assist subcontractors in successfully achieving key project tasks. Also apparent from the data included in Table III is the observation that contract modifications occurred more towards the beginning and middle phases of the project than at the end. This may be a function of product definition and clarity as more tangible results are realized. To the extent that contract modifications affect variance amounts is less conclusive from observation of the data. A final factor that appeared to adversely affect development costs in this specific case is that of material delays of singularly less critical off-the-shelf components and their successful integration with other component parts. These difficulties caused severe delays in the project, unproductive efforts to find alternative sources of supplies, and excessive utilization of expensive engineering labor in redesign efforts.

D. CHAPTER SUMMARY

This chapter presented and analyzed the actual and estimated development costs associated with the CSTV project. Data were presented in chronological order as they were experienced throughout the life of the project. Modifications to the contract, as requested by the government, were identified. However primary attention was paid to the cost overruns. Reasons were then given for the resulting cost variances. Finally, several conclusions concerning factors which appeared to significantly affect development costs where reached.

V. PRINCIPLE FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

A. PRINCIPLE FINDINGS AND CONCLUSIONS

The primary objective of this study was to determine what methods were used in estimating the development costs associated with an actual state-of-the-art extension project. Lockheed Missiles and Space Company, Inc. and the development of the CSTV project provided the basis for this inquiry. The principle findings and conclusions were derived from personal interviews with key LMSC management personnel and relevant documentation collected and analyzed at LMSC and the Lockheed Naval Plant Representative Office; both located in Sunnyvale, California. These findings and conclusions are presented and discussed as follows.

A relatively complex and comprehensive process known as the LMSC Estimating System, was utilized to predict the development cost of the CSTV project. This process consists of a series of events within phases. Along with producing creditable cost estimates, the estimating process was used to assign task assignments to accountable personnel, and to thoroughly document cost estimates for internal and government audit purposes.

A combination of cost estimating techniques were employed within the guidelines of the LMSC Estimating System to predict the development cost of the CSTV project. Although the Engineering or "Bottom-Up" cost estimating technique was predominantly utilized on the CSTV project, the associated program method was relied upon to a lesser extent when program comparisons were considered appropriate. Parametric techniques were used in the final cost estimation review phase to provide "sanity" checks. They were not relied upon in the primary stages of generating cost estimates.

The CSTV project was organized around a project team approach. Numerous managerial requirements, including tight project control, and the establishment of a single responsible project manager, were accomplished in this manner. This project team organizational structure was based upon the successes experienced by several Lockheed companies involved with similar SOA extension projects previously undertaken.

Despite the elaborate nature of the LMSC cost estimation process employed, significant cost growth and overruns (variances) resulted. The final CSTV project cost increased dramatically over the initial estimated costs. This led the researcher to conclude that the process of cost estimation utilized by LMSC to estimate the CSTV project's costs was complicated by the degree of technological extension required.

Task uncertainties associated with the development of the CSTV project appeared to be the major contributor to the cost overruns experienced. Although significant preliminary design work was conducted prior to the award of the CSTV contract, numerous additional engineering labor hours were incurred as project engineers attempted to adequately define the CSTV. These design efforts appeared to lessen in the later stages of project development.

B. RECOMMENDATIONS

1. Government Officials responsible for SOA extension projects should continue to thoroughly review cost estimates submitted by contractors. Emphasis and attention should be placed on whether, or to what extent, the contractor fully understands the requirements of the project.

2. Continue to insure that contract documentation such as the SOW, CDRL, and WBS for state-of-the-art extension projects is clearly defined and understood by all concerned parties. This may help to minimize the possibility of project misunderstandings and underestimation of the costs associated with project development.

3. Move towards more fixed price contracts that place greater risk upon the contractor. SOA extension projects appear to be filled with numerous uncertainties caused primarily by the degree to which extended technology is required. The process of estimating expected costs that adequately accounts for project uncertainties was not successfully realized in this particular case and resulted in the government incurring significantly more costs than anticipated. This also may be the experience with cost estimation process employed in other projects.

C. RECOMMENDATIONS FOR FURTHER RESEARCH

If total contract cost growth is used as a measure of effectiveness, it is apparent that the process utilized in estimating the final project cost was not, for various reasons, completely successful in the case of the CSTV project. This study involved one specific case and cannot reasonably be expected to fully support any broad based theoretical conclusions on its own. It is possible but unlikely that the cost growth and overruns are unique to this particular case. Therefore, it is recommended that further case studies involving SOA extension projects be conducted to determine if similar difficulties are encountered. The focus of these additional case studies should be to provide further identification of the factors affecting cost estimates and the means by which the degree of required technological extension is incorporated into the cost estimation process. Greater insights into the process involved would assist Navy budget analysts and program managers in more accurately determining cost requirements and impacts of SOA extension projects.

D. FINAL SUMMARY

As a final summary of the information presented and discussed in this report, the primary and subsidiary research questions will be reinstated and briefly answered.

* Primary Research Question:

What methods were employed by a major Department of the Navy contractor to predict the development costs associated with an actual state-of-the-art (SOA) extension project?

Answer: A combination of the engineering (primary technique), associated program, and parametric (used by LMSC cost estimation reviewing authorities) techniques within the framework of the LMSC Estimating System.

Subsidiary Research Questions:

1. What were the expected costs, actual costs, and variances experienced during the development of the SOA extension project?

   Answer: Details on costs and variances are provided in Chapter IV and in Appendix D. Significant cost variances and contract growth resulted.

2. What were the reasons for the variances experienced?

   Answer: The primary reason stems from the costs associated with the engineering re design efforts required as a consequence of the uncertainty associated with the advanced and complex technological nature of the CSTV project. Additionally, an incomplete understanding of contract requirements lead to unexpected cost increases.

3. Which development cost categories had the most effect on total project cost?, i.e. what were the "cost drivers"?

   Answer: In the early stages of the project, the engineering labor cost to adequately define the CSTV product was the cost category most affecting the project cost. In the later stages, costs were associated with subcontractor performance.

4. What organizational design or structure was utilized during the SOA project; and how does that design affect cost management?

Answer: A project team approach was utilized; the design of which was adapted from successful SOA extension projects previously undertaken by other organizations within the Corporation. Concern over project costs received a greater degree of management attention than would have occurred if more traditional organizational approaches had been adopted.

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APPENDIX A
CSTV STATEMENT OF WORK

The Statement of Work describes the tasks to be preformed by LMSC in the design, construction, and test of the Control System Test Vehicle (CSTV) and support equipment. This information was reproduced from the LMSC management proposal for the CSTV project submitted to NAVSEA on 25 July 1978.

SCOPE

The contractor shall make maximum use of all data developed and documented under Contract N0004-78-C-5309. All work to be preformed under this contract is generally described below:

ITEM

0001- Design, construct, test and deliver one (1) Control System Test Vehicle and one (1) set of support equipment as defined herein.

0002- Provide interim repair parts, supplies and services as ordered by the Administrative Contracting Officer (ACO) and authorized by contract modification.

0003- Prepare and deliver as defined on the Contract Data Requirements List.

PERIOD OF PERFORMANCE

The contractor's effort described in this Statement of Work shall be accomplished during the periods specified below:

ITEM

0001- From contract award through the twelfth (12) month after contract award.

0002- As specified in the authorizing contract modification.

0003- From contract award through the fourteenth (14) month after contract award.

APPLICABLE DOCUMENTS

The following documents of the issues and date specified form a part of this SOW to the extent specified herein.

MILITARY

NO-794-78-003	April 1978	"Control System Test Vehicle and Equipment Specification"
Exhibit A to	10 May 1978	ASCOP Test Vehicle Contract N00024-78-PR-31018 Data Requirements List (DD Form 1423)

TASK DESCRIPTION

This section defined the tasks to be performed by the contractor and the responsibility interfaces between the contractor, NAVSEA, and other participating activities. Paragraph numbers herein are directly relatable to the Work Breakdown Structure (WBS) included in the Control System Test Vehicle Specification, NO-794-78-003 and the contractor's Management Proposal.

Model Vehicle. Design and construct one Test Vehicle in accordance with the requirements of Specification NO-794-78-003 and Appendixes 1 through 5 thereof.

- Perform Design Studies, Design Analyses, and Producibility Studies to support the detail design.

- Integrate GFE into the CSTV design, with specific emphasis on the Inertial Measurement Unit (IMU) and the Control and Recording System (CRS).
- Generate detail design drawings.
- Prepare a design Analysis Report (CDRL Sequence A004).
- Prepare Critical Design Review Data (CDRL Sequence A003), and support the Critical Design Review.
- Support internal design reviews.
- Provide technical direction to subcontractors.
- Manufacture, inspect, assemble, and test the Test Vehicle.
- Prepare "As-built" drawings (CDRL Sequence A00D).

Support Equipment. Design and construct one set of Support Equipment consisting of the items listed below in accordance with the requirements of Specification NO-794-78-003, Appendix 6.

- One control and display system.
- Twelve (12) dollies.
- Shipping containers as required.
- One (1) external power supply.
- Miscellaneous slings, umbilicals, etc.

In support of this requirement, the contractor shall:

- Perform design studies and analysis to support the detail design.
- Generate detail design drawings.
- Prepare Critical Design Review Data (CDRL Sequence A004), and support the Critical Design Review.

- Support internal design reviews.
- Provide technical direction to suppliers of purchased equipment.
- Manufacture, inspect, assemble, and test the support equipment.
- Provide interface information as required to facilitate Government modification of the GFE trailer and sled.

Test and Evaluation. The contractor shall conduct a test and evaluation program to verify that the vehicle, including contractor furnished equipment and Government furnished equipment, performs in accordance with the requirements of Specification NO-794-78-003.

- Conduct development tests of selected items as required to evaluate performance and reliability.
- Prepare a factory acceptance test plan covering factory-level tests and special tests for Navy approval (CDRL Sequence A00A).
- Conduct factory acceptance tests in accordance with the approved test plan, analyze test data, and prepare test reports (CDRL Sequence A00B).
- Support special tests at the Ocean Simulation Facility, Panama City, FL, analyze test data, and prepare special report (CDRL A00C).

System Engineering. This task covers the integrating activities related to applied engineering disciplines. This activity will:

- Coordinate with NAVSEA and GFE suppliers to define requirements and establish physical and functional interfaces between the vehicle, support equipment, and the related GFE.
- Maintain coordination with NAVSEA to develop software interfaces for the GFE IMU to assure successful operation of the CSTV.

- Maintain positive interface control between the vehicle and support equipment.
- Conduct internal design reviews.
- Prepare the Critical Design Review Agenda (CDRL Sequence A003), CDR Data (CDRL Sequence A002), and conduct the CDR.
- Review Test Plans and Test Reports.
- Prepare for Navy approval, a Quality Assurance Plan (CDRL Sequence A00E) and conduct a quality assurance program in accordance therewith.
- Conduct and monitor Reliability and Maintainability programs.
- Conduct and monitor Systems Safety and Human Engineering programs.
- Prepare requests for approval of nonstandard parts (CDRL Sequence A007).
- Prepare Quarterly Technical Progress Reports (CDRL Sequence A009) and a Final Engineering Report.
- Construct full scale soft mock-ups of the test vehicle and support equipment, as required.

Systems Management. The contractor shall provide and maintain an organization structure to ensure effective direction and management that will:

- Formulate decisions and exercise technical management.
- Establish rational priorities and clearly defined responsibilities within each discipline.
- Monitor and evaluate activities of all disciplines to ensure feedback of complete and accurate information for in-depth program visibility.
- Establish and maintain a program master schedule encompassing all tasks necessary for program accomplishment.

- Negotiate resource allocations with all organizations, document results, and release authorizing documents for resource utilization.
- Coordinate the evaluation and selection of qualified subcontractors and suppliers.
- Administer all subcontract and purchase effort.
- Prepare Monthly Letter Status Reports (CDRL Sequence A001).
- Ensure thorough evaluation and proper authorization of all design changes.
- Confirm the incorporation of all authorized changes into hardware.
- Prepare Engineering Change Proposals, Deviations, and Waivers (CDRL Sequence A008).
- Ensure the proper preparation and timely submission of all data specified by the Contract Data Requirements List (DD Form 1423).
- Perform logistical studies and analyses.
- Prepare a list of recommended spare parts.
- Prepare a list of special and general purpose electronic test equipment (CDRL Sequence A005).
- Prepare a Technical Maintenance Manual, Operator's Manual and Parts List (CDRL Sequence A006).
- Perform liaison with the government and GFE suppliers to ensure integration of GFE Operation and Maintenance Manuals.
- Inspect and test GFE as received to ensure proper operation before installation.
- Provide protection and control of GFE to prevent damage during handling and storage.
- Provide field support as directed by the ACO under Item 0002 of the contract.

APPENDIX B

CONTRACT PRICING PROPOSAL (21 JUL 78)

DEPARTMENT OF DEFENSE
CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT) CPFF

Form Approved
Budget Bureau No. 22-R100

This form is for use when (i) submission of cost or pricing data (see ASPR 3-807.3) is required and (ii) substitution for the DD Form 633 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR: Lockheed Missiles & Space Company, Inc.

SUPPLIES AND/OR SERVICES TO BE FURNISHED: Design, fabricate, and test of a Control System Test Vehicle and equipment.

HOME OFFICE ADDRESS: P. O. Box 504, Sunnyvale, CA 94086

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED:

TOTAL AMOUNT OF PROPOSAL: $ 2,468,365

GOVT SOLICITATION NO.: RFP N00024-78-R-5352

DETAIL DESCRIPTION OF COST ELEMENTS

	EST. HOURS	RATE/HOUR	EST COST ($)	TOTAL EST COST 1/	REFER-ENCE 2/
1. DIRECT MATERIAL (Itemize on Exhibit A)					
a. PURCHASED PARTS			$441,631		
b. SUBCONTRACTED ITEMS			243,250		
c. OTHER - (1) RAW MATERIAL CMM			19,113		
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				$703,994	9-2
2. MATERIAL OVERHEAD 3/ (Rate % X $ base =)				96,613	9-3
3. DIRECT LABOR (Specify)					
	47,644	$11.014*	524,743		
*Average Rate					
TOTAL DIRECT LABOR				$524,743	9-4
4. LABOR OVERHEAD (Specify Department or Cost Center) 3/	O.H. RATE	X BASE =	EST COST ($)		
Development Overhead		31,140Hr	$391,829		
Manufacturing Overhead		16,504Hr	287,806		
TOTAL LABOR OVERHEAD				$679,635	9-5
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			$8,300		
b. PER DIEM OR SUBSISTENCE			3,696		
TOTAL TRAVEL				$11,996	9-6
8. CONSULTANTS (Identify - purpose - rate)			EST COST ($)		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				95,515	5-2
10. TOTAL DIRECT COST AND OVERHEAD				$2,112,496	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.) 3/				164,007	9-9
12. ROYALTIES 4/					
13. TOTAL ESTIMATED COST				$2,276,503	
14. FEE OR PROFIT				191,862	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				$2,468,365	

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)

RFP N00024-78-R-6352 (S), Dated 78 June 07

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE: R.R. Messenger, Contract Estimator

SIGNATURE: R R Messenger

NAME OF FIRM: Lockheed Missiles & Space Company, Inc.

DATE OF SUBMISSION: 21 July 1978

EXHIBIT A - SUPPORTING SCHEDULE (Specify. If more space is needed, use blank sheets)		
COST EL NO	ITEM DESCRIPTION (See footnote 5)	EST COST ($)
1	Reproduction	$ 7,188
2	Computer	63,414
3	CAS 414	19,306
4	Overtime Premium	5,607
	TOTAL OTHER DIRECT COSTS	$95,515

I. HAVE THE DEPARTMENT OF DEFENSE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, OR THE ATOMIC ENERGY COMMISSION PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO (If yes, identify below.) Continuing Audit

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, P.O. Box 504, Sunnyvale, CA 94-86	(408) 742-5991

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO (If yes, identify on a separate page.)

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT? Bi-weekly Billings

[ ] YES [X] NO (If yes, identify.) [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT (or, do you have any independently financed (IR & D) projects) FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO (If yes, identify)

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN ASPR, SECTION XV (See 3-807.2 (c) (2))?

[X] YES [ ] NO (If no, explain on a separate page.)

INSTRUCTIONS TO OFFERORS

1. The purpose of this form is to provide a standard format by which the offeror submits to the Government a summary of incurred and estimated cost *(and attached supporting information)* suitable for detailed review and analysis. Prior to the award of a contract resulting from this proposal the offeror shall, under the conditions stated in ASPR 3-807.3, be required to submit a Certificate of Current Cost or Pricing Data (see ASPR 3-807.3(e) and 3-807.4).

2. As part of the specific information required by this form, the offeror must submit with this form, and clearly identify as such, cost or pricing data (that is, data which is verifiable and factual and otherwise as defined in ASPR 3-807.3(e)). In addition, he must submit with this form any information reasonably required to explain the offeror's estimating process, including:
   a. the judgmental factors applied and the mathematical or other methods used in the estimate including those used in projecting from known data, and
   b. the contingencies used by offeror in his proposed price.

3. Attach separate pages if necessary and identify in this column the attachment in which the information supporting or otherwise relating to the specific cost element may be found. When attachment of supporting cost or pricing data to this form is impracticable, the data will be specifically identified and described *(with schedules as appropriate)*, and made available to the Contracting Officer or his representative upon request.

4. The formats for the "Cost Elements" and the "Proposed Contract Estimate" are not intended as rigid requirements. These may be presented in different format with the prior approval of the Contracting Officer if required for more effective and efficient presentation. In all other respects this form will be completed and submitted without change.

5. By submission of this proposal offeror, if selected for negotiation, grants to the Contracting Officer, or his authorized representative, the right to examine, for the purpose of verifying the cost or pricing data submitted, those books, records, documents and other supporting data which will permit adequate evaluation of such cost or pricing data, along with the computations and projections used therein. This right may be exercised in connection with any negotiations prior to contract award.

FOOTNOTES

1/ Enter in this column those necessary and reasonable costs which in the judgment of the offeror will properly be incurred in the efficient performance of the contract. When any of the costs in this column have already been incurred (e.g., on a letter contract or change order), describe them on an attached supporting schedule. Identify all sales and transfers between your plants, divisions, or organizations under a common control, which are included at other than the lower of cost to the original transferor or current market price.

2/ When space in addition to that available in Exhibit A is required, attach separate pages as necessary and identify in this "Reference" column the attachment in which information supporting the specific cost element may be found. No standard format is prescribed; however, the cost or pricing data must be accurate, complete and current, and the judgment factors used in projecting from the data to the estimates must be stated in sufficient detail to enable the Contracting Officer to evaluate the proposal. For example, provide the basis used for pricing materials such as by vendor quotations, shop estimates, or invoice prices; the reason for use of overhead rates which depart significantly from experienced rates (reduced volume, a planned major re-arrangement, etc.); or justification for an increase in labor rates (anticipated wage and salary increases, etc.). Identify and explain any contingencies which are included in the proposed price, such as anticipated costs of rejects and defective work, or anticipated technical difficulties.

3/ Indicate the rates used and provide an appropriate explanation. Where agreement has been reached with Government representatives on the use of forward pricing rates, describe the nature of the agreement. Provide the method of computation and application of your overhead expense, including cost breakdown and showing trends and budgetary data as necessary to provide a basis for evaluation of the reasonableness of proposed rates.

4/ If the total royalty cost entered here is in excess of $250 provide on a separate page (or on DD Form 783, Royalty Report) the following information on each separate item of royalty or license fee; name and address of licensor; date of license agreement; patent numbers, patent application serial numbers, or other basis on which the royalty is payable; brief description, including any part or model numbers of each contract item or component on which the royalty is payable; percentage or dollar rate of royalty per unit; unit price of contract item; number of units; and total dollar amount of royalties. In addition, if specifically requested by the contracting officer, a copy of the current license agreement and identification of applicable claims of specific patents shall be provided.

5/ Provide a list of principal items within each category indicating known or anticipated source, quantity, unit price, competition obtained, and basis of establishing source and reasonableness of cost.

* U.S. GOVERNMENT PRINTING OFFICE [illegible]

APPENDIX C

CONTRACT PRICING PROPOSAL (18 OCT 78)

DEPARTMENT OF DEFENSE CONTRACT PRICING PROPOSAL (RESEARCH AND DEVELOPMENT)	CPFF	Form Approved Budget Bureau No. 22-R100
This form is for use when (i) submission of cost or pricing data (see ASPR 3-807.3) is required and (ii) substitution for the DD Form 633 is authorized by the contracting officer		PAGE NO. / NO. OF PAGES
NAME OF OFFEROR Lockheed Missiles & Space Company, Inc.	SUPPLIES AND/OR SERVICES TO BE FURNISHED Design, fabricate, and test of a Control Test Vehicle and Equipment	
HOME OFFICE ADDRESS P.O. Box 504 Sunnyvale, CA 94086		
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED LMSC, Sunnyvale, CA	TOTAL AMOUNT OF PROPOSAL $ 1,774,402	GOV'T SOLICITATION NO. RFP N00024-78-R-5352

DETAIL DESCRIPTION OF COST ELEMENTS

	EST COST ($)	TOTAL EST COST	REFERENCE
1. DIRECT MATERIAL (Itemize on Exhibit A)			
a. PURCHASED PARTS	208,785		
b. SUBCONTRACTED ITEMS and Purchased Services	178,264		
c. OTHER - (1) RAW MATERIAL (CMM)	9,007		
(2) YOUR STANDARD COMMERCIAL ITEMS			
(3) INTERDIVISIONAL TRANSFERS (At other than cost)			
TOTAL DIRECT MATERIAL		296,056	
2. MATERIAL OVERHEAD (Rate % X $ base =)		54,229	

3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Engineering	15,082	12.339	193,543		
Product Assurance	2,200	11.022	24,308		
Technical Publications	466	9.756	4,566		
Test Engineers	[illegible]	11.002	45,390		
Manufacturing	17,412	9.525	165,843		
*Average Rate TOTAL DIRECT LABOR				434,550	
4. LABOR OVERHEAD (Specify Department or Cost Center)	O.H. RATE	X BASE =	EST COST ($)		
Development Overhead	13,232*	26.941	356,479		
Manufacturing Overhead	16,240	12.392	201,250		
TOTAL LABOR OVERHEAD					

	EST COST ($)	TOTAL EST COST	REFERENCE
5. SPECIAL TESTING (Including field work at Government installations)			
TOTAL SPECIAL TESTING			
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)			
7. TRAVEL (If direct charge) (Give details on attached Schedule)			
a. TRANSPORTATION	[illegible]		
b. PER DIEM OR SUBSISTENCE	[illegible]256		
TOTAL TRAVEL		7,589	
8. CONSULTANTS (Identify - purpose - rate)			
TOTAL CONSULTANTS			
9. OTHER DIRECT COSTS (Itemize on Exhibit A)		61,515	
10. TOTAL DIRECT COST AND OVERHEAD		1,512,166	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)		147,379	
12. ROYALTIES			
13. TOTAL ESTIMATED COST			
14. FEE OR PROFIT		114,857	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT		1,774,402	

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)
Control System Test Vehicle (CSTV) Program SER: 263
RFP No. N00024-78-R-5352(S) "Best and Final", SEA-0253V: TVG
and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
R. R. Messenger Program Cost Controller	R R Messenger
NAME OF FIRM Lockheed Missiles & Space Company, Inc.	DATE OF SUBMISSION 10/18/78

EXHIBIT A – SUPPORTING SCHEDULE *(Specify. If more space is needed, use blank sheets)*

COST EL NO.	ITEM DESCRIPTION (See footnote 5)	EST COST ($)
	9. Other Direct Costs	
1	Reproduction	[illegible],269
2	Computer	[illegible],654
3	CAS 414	1[illegible],326
4	Overtime Premium	[illegible],669
	Total Other Direct Costs	51,616

I. HAVE THE DEPARTMENT OF DEFENSE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, OR THE ATOMIC ENERGY COMMISSION PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

☒ YES ☐ NO *(If yes, identify below.)* Continuing Audit

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, P.O. Box 504, Sunnyvale, CA 94086	(408) 742-5991

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

☒ YES ☐ NO *(If yes, identify on a separate page.)* Attached List

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT? Bi-Weekly Billings

☐ YES ☒ NO *(If yes, identify.)*: ☐ ADVANCE PAYMENTS ☐ PROGRESS PAYMENTS OR ☐ GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT (or, do you have any independently financed (IR & D) projects) FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN ASPR, SECTION XV (See 3-807.2(c)(2))?

☒ YES ☐ NO *(If no, explain on a separate page.)*

INSTRUCTIONS TO OFFERORS

1. The purpose of this form is to provide a standard format by which the offeror submits to the Government a summary of incurred and estimated cost (and attached supporting information) suitable for detailed review and analysis. Prior to the award of a contract resulting from this proposal the offeror shall, under the conditions stated in ASPR 3-807.3, be required to submit a Certificate of Current Cost or Pricing Data (see ASPR 3-807.3(e) and 3-807.4).

2. As part of the specific information required by this form, the offeror must submit with this form, and clearly identify as such, cost or pricing data (that is, data which is verifiable and factual and otherwise as defined in ASPR 3-807.3(e)). In addition, he must submit with this form any information reasonably required to explain the offeror's estimating process, including:

a. the judgmental factors applied and the mathematical or other methods used in the estimate including those used in projecting from known data, and

b. the contingencies used by offeror in his proposed price.

3. Attach separate pages if necessary and identify in this column the attachment in which the information supporting or otherwise relating to the specific cost element may be found. When attachment of supporting cost or pricing data to this form is impracticable, the data will be specifically identified and described (with schedules as appropriate), and made available to the Contracting Officer or his representative upon request.

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5. By submission of this proposal offeror, if selected for negotiation, grants to the Contracting Officer, or his authorized representative, the right to examine, for the purpose of verifying the cost or pricing data submitted, those books, records, documents and other supporting data which will permit adequate evaluation of such cost or pricing data, along with the computations and projections used therein. This right may be exercised in connection with any negotiations prior to contract award.

FOOTNOTES

1/ Enter in this column those necessary and reasonable costs which in the judgment of the offeror will properly be incurred in the efficient performance of the contract. When any of the costs in this column have already been incurred (e.g., on a letter contract or change order), describe them on an attached supporting schedule. Identify all sales and transfers between your plants, divisions, or organizations under a common control, which are included at other than the lower of cost to the original transferor or current market price.

2/ When space in addition to that available in Exhibit A is required, attach separate pages as necessary and identify in this "Reference" column the attachment in which information supporting the specific cost element may be found. No standard format is prescribed; however, the cost or pricing data must be accurate, complete and current, and the judgment factors used in projecting from the data to the estimates must be stated in sufficient detail to enable the Contracting Officer to evaluate the proposal. For example, provide the basis used for pricing materials such as by vendor quotations, shop estimates, or invoice prices; the reason for use of overhead rates which depart significantly from experienced rates (reduced volume, a planned major rearrangement, etc.); or justification for an increase in labor rates (anticipated wage and salary increases, etc.). Identify and explain any contingencies which are included in the proposed price, such as anticipated costs of rejects and defective work, or anticipated technical difficulties.

3/ Indicate the rates used and provide an appropriate explanation. Where agreement has been reached with Government representatives on the use of forward pricing rates, describe the nature of the agreement. Provide the method of computation and application of your overhead expense, including cost breakdown and showing trends and budgetary data as necessary to provide a basis for evaluation of the reasonableness of proposed rates.

4/ If the total royalty cost entered here is in excess of $250 provide on a separate page (or on DD Form 783, Royalty Report) the following information on each separate item of royalty or license fee: name and address of licensor; date of license agreement; patent numbers, patent application serial numbers, or other basis on which the royalty is payable; brief description, including any part or model numbers of each contract item or component on which the royalty is payable; percentage or dollar rate of royalty per unit; unit price of contract item; number of units; and total dollar amount of royalties. In addition, if specifically requested by the contracting officer, a copy of the current license agreement and identification of applicable claims of specific patents shall be provided.

5/ Provide a list of principal items within each category indicating known or anticipated source, quantity, unit price, competition obtained, and basis of establishing source and reasonableness of cost.

APPENDIX D

CSTV PROJECT COST BREAKDOWN

CSTV PROJECT COST BREAKDOWN

	(1) Original Cost Estimate	(2) Contract Modifications reported on 24 Aug 79	(3) Contract Modifications reported on 12 Nov 79	(4) Contract Modifications reported on 29 Feb 80	(5) Contract Modifications reported on 24 Jun 80	(6) Contract Adjustment reported on 10 Dec 80	Σ (Col 1 thru Col 6) (7) Total Contract Modifications
DIRECT LABOR HOURS:							
Development	26,941	562	286	1,543	2,743		32,075
Manufacturing	12,392	1,276	0	403	1,044		15,115
Remote Pool	0	0	0	0	0		0
Total Hours	39,333	1,838	286	1,946	3,787		47,190
COSTS:							
Direct Labor	436,511	21,159	3,409	25,363	52,559		102,490
Overhead and G&A	731,339	33,195	5,145	36,890	78,646		153,876
Overtime Premium	4,668	0	0	125	0		125
Material	210,899	20,347	26,338	24,503	59,207		130,395
Common Minor Materials	9,063	874	1,133	1,054	2,545		5,606
Purchased Services	4,800	0	0	7,100	0		7,100
Subcontracts	173,464	0	145,907	26,250	28,290		200,447
Burdens	54,075	4,266	8,878	6,019	16,368		35,531
Travel	7,588	0	1,584	0	1,466		3,050
Reproduction	5,968	276	43	292	576		1,187
Computer	44,444	2,808	549	1,280	160		4,797
Interdivision	0	0	0	0	0		0
Other	0	0	0	0	0	75,000	75,000
Total Cost	$1,682,819	$82,925	$192,986	$128,876	$239,817	$75,000	$719,604

CSTV PROJECT COST BREAKDOWN

(8)	(9)	(10)	(11)	(12)	(13)	Σ(Col 8 thru Col 13) (14)	Col 7 + Col 14 (15)	Col 1 + Col 15 (16)
Variance # 1	Variance # 2	Variance # 3	Variance # 4	Variance # 5	Variance #6	Total Variance	Total CSTV Project Cost Growth and Variance	Final CSTV Project Cost
3,755	13,109	1,300	7,410	1,453	2,148	27,027	59,102	86,043
3,254	(4,861)	6,443	(2,590)	600	(351)	2,846	17,961	30,353
0	16	23	79	114	52	232	232	232
7,009	8,264	7,766	4,899	2,167	1,849	30,105	77,295	116,628
113,720	96,276	97,139	59,389	27,120	29,722	423,366	525,856	962,367
151,076	145,277	180,006	91,685	43,266	38,711	650,021	803,897	1,535,236
9,780	(7,069)	1,608	(492)	2	3,073	6,902	7,027	11,695
85,869	22,318	26,999	21,807	12,995	(15,062)	154,926	285,321	496,220
2,296	323	3,593	2,266	50	(68)	8,460	14,066	23,129
(2,117)	16,553	(5,736)	(7,300)	884	(1,215)	1,069	8,169	12,969
122,406	89,050	27,069	23,870	4,942	45,642	312,979	513,426	686,890
28,479	10,426	13,030	7,184	(2,669)	(1,039)	55,411	90,942	145,017
0	(2,825)	32	12,534	6,976	(1,823)	14,894	17,944	25,532
(1,055)	(221)	617	(1,252)	(450)	1,642	(719)	468	6,436
14,025	5,330	976	279	(2,606)	3,287	21,291	26,088	70,532
319	319	(319)	0	0	0	319	319	319
0	16	0	0	0	(71,520)	(71,504)	3,496	3,496
$524,798	$375,773	$345,014	$209,970	$90,510	$31,350	$1,577,415	$2,297,019	$3,979,838

VARIANCE ANALYSIS #1

24 Aug 79

	(1) Actual Cummulative Cost to date	+	(2) Estimated Cost to Complete	=	(3) Total Estimated Cost	(4) Cummulative Contract Cost to date *	(5) (Col.3 minus Col.5) Variance
DIRECT LABOR HOURS:							
Development	21,619		10,353		31,972	28,217	3,755
Manufacturing	6,279		9,929		16,208	12,954	3,254
Total	27,898		20,282		48,180	41,171	7,009
COST:							
Direct Labor	336,318		235,072		571,390	457,670	113,720
Overhead and G&A Expense	515,456		400,140		915,596	763,721	151,875
Overtime Premium	4,898		9,550		14,448	4,668	9,780
Material	241,568		75,547		317,115	231,246	85,869
Common Minor Material	8,984		3,249		12,233	9,937	2,296
Purchased Services	2,683		0		2,683	4,800	(2,117)
Subcontract	280,370		15,500		295,870	173,464	122,406
Burdens	67,023		19,797		86,820	58,341	28,479
Travel	3,825		3,763		7,588	7,588	0
Reproduction	2,147		3,042		5,189	6,244	(1,055)
Computer	54,277		7,000		61,277	47,252	14,025
Interdivision	319		0		319	0	319
Others	14		0		14	813	(799)
TOTAL COST	$1,517,882		$772,660		$2,290,542	$1,765,744	$524,798

* Allowable costs to date + proposed contract modifications.

VARIANCE ANALYSIS #2

12 Nov 79

	(1) Actual Cummulative Cost to date	+	(2) Estimated Cost to Complete	=	(3) Total Estimated Cost	(4) Cummulative Contract Cost to date *	(5) (Col.3 minus Col.5) Variance
DIRECT LABOR HOURS:							
Development	30,839		14,528		45,367	32,258	13,109
Manufacturing	10,029		1,318		11,347	16,208	(4,861)
Remote Pool	16		0		16	0	16
Total	40,884		15,846		56,730	48,466	8,264
COST:							
Direct Labor	489,168		181,907		671,075	574,799	96,276
Overhead and G&A Expense	758,379		308,027		1,066,406	921,609	144,797
Overtime Premium	5,319		2,060		7,379	14,448	(7,069)
Material	366,174		18,600		384,774	362,456	22,318
Common Minor Material	13,762		744		14,506	14,183	323
Purchased Services	16,356		0		16,356	(197)	16,553
Subcontract	506,357		53,600		559,957	470,907	89,050
Burdens	104,158		6,554		110,712	100,286	10,426
Travel	4,994		1,902		6,896	9,721	(2,825)
Reproduction	2,634		2,377		5,011	5,232	(221)
Computer	60,609		6,000		66,609	61,277	5,332
Interdivision	319		0		319	0	319
Others	14		0		14	(480)	494
TOTAL COST	$2,328,243		$581,771		$2,910,014	$2,534,241	$375,773

* Allowable costs to date + proposed contract modifications.

VARIANCE ANALYSIS #3

29 Feb 80

	(1) Actual Cummulative Cost to date	+	(2) Estimated Cost to Complete	=	(3) Total Estimated Cost	(4) Cummulative Contract Cost to date *	(5) (Col.3 minus Col.5) Variance
DIRECT LABOR HOURS:							
Development	39,121		8,375		47,496	46,196	1,300
Manufacturing	13,188		5,719		18,907	12,464	6,443
Remote Pool	39		0		39	16	23
Total	52,348		14,094		66,442	58,676	7,766
COST:							
Direct Labor	627,219		166,358		793,577	696,438	97,139
Overhead and G&A Expense	981,972		300,956		1,282,928	1,102,922	180,006
Overtime Premium	6,779		2,333		9,112	7,504	1,608
Material	386,943		30,330		417,273	390,274	26,999
Common Minor Material	16,819		1,517		18,336	14,743	3,593
Purchased Services	16,520		4,080		20,600	26,336	(5,736)
Subcontract	543,481		40,665		584,146	557,077	27,069
Burdens	115,607		9,566		125,173	112,143	13,030
Travel	6,379		0		6,379	6,347	32
Reproduction	3,806		2,114		5,920	5,303	617
Computer	66,214		3,200		69,414	68,438	976
Interdivision	319		0		319	638	(319)
Others	14		0		14	14	0
TOTAL COST	$2,772,072		$561,119		$3,333,191	$2,988,177	$345,014

* Allowable costs to date + proposed contract modifications.

VARIANCE ANALYSIS #4

24 Jun 80

	(1) Actual Cummulative Cost to date	+	(2) Estimated Cost to Complete	=	(3) Total Estimated Cost	(4) Cummulative Contract Cost to date *	(5) (Col.3 minus Col.5) Variance
DIRECT LABOR HOURS:							
Development	50,384		7,265		57,649	50,239	7,410
Manufacturing	16,116		1,245		17,361	19,951	(2,590)
Remote Pool	118		0		118	39	79
Total	66,618		8,510		75,128	70,229	4,899
COST:							
Direct Labor	795,237		110,288		905,525	846,136	59,389
Overhead and G&A Expense	1,277,877		175,382		1,453,259	1,361,574	91,685
Overtime Premium	8,370		250		8,620	9,112	(492)
Material	434,337		63,950		498,287	476,480	21,807
Common Minor Material	19,949		3,198		23,147	20,881	2,266
Purchased Services	9,220		4,080		13,300	20,600	(7,300)
Subcontract	573,516		62,790		636,306	612,436	23,870
Burdens	129,395		19,330		148,725	141,541	7,184
Travel	8,808		11,571		20,379	7,845	12,534
Reproduction	4,223		1,021		5,244	6,496	(1,252)
Computer	66,946		2,905		69,851	69,572	279
Interdivision	319		0		319	319	0
Others	16		0		16	16	0
TOTAL COST	$3,328,213		$454,765		$3,782,978	$3,573,008	$209,970

* Allowable costs to date + proposed contract modifications.

VARIANCE ANALYSIS #5

29 Aug 80

	(1) Actual Cummulative Cost to date	+	(2) Estimated Cost to Complete	=	(3) Total Estimated Cost	(4) Cummulative Contract Cost to date *	(5) (Col.3 minus Col.5) Variance
DIRECT LABOR HOURS:							
Development	56,647		2,455		59,102	57,649	1,453
Manufacturing	16,691		1,270		17,961	17,361	600
Remote Pool	232		0		232	118	114
Total	73,570		3,725		77,295	75,128	2,167
COST							
Direct Labor	884,440		48,205		932,645	905,525	27,120
Overhead and G&A Expense	1,417,196		79,329		1,496,525	1,453,259	43,266
Overtime Premium	8,622		0		8,622	8,620	2
Material	452,581		58,701		511,282	498,287	12,995
Common Minor Material	20,849		2,348		23,197	23,147	50
Purchased Services	13,584		600		14,184	13,300	884
Subcontract	608,786		32,462		641,248	636,306	4,942
Burdens	129,492		16,564		146,056	148,725	(2,669)
Travel	18,365		8,990		27,355	20,379	6,976
Reproduction	4,347		447		4,794	5,244	(450)
Computer	67,245		0		67,245	69,851	(2,606)
Interdivision	319		0		319	319	0
Others	16		0		16	16	0
TOTAL COST	$3,625,842		$247,646		$3,873,488	$3,782,978	$90,510

* Allowable costs to date + proposed contract modifications.

VARIANCE ANALYSIS #6

12 Feb 81

	(1) Actual Cummulative Cost to date	+	(2) Estimated Cost to Complete	=	(3) Total Estimated Cost	(4) Cummulative Contract Cost to date *	(5) (Col.3 minus Col.5) Variance
DIRECT LABOR HOURS:							
Development	61,110		140		61,250	59,102	2,148
Manufacturing	17,410		200		17,610	17,961	(351)
Remote Pool	284		0		284	232	52
Total	78,804		340		79,144	77,295	1,849
COST:							
Direct Labor	957,842		4,525		962,367	932,645	29,722
Overhead and G&A Expense	1,526,952		8,284		1,535,236	1,496,525	38,711
Overtime Premium	11,695		0		11,695	8,622	3,073
Material	495,220		1,000		496,220	511,282	(15,062)
Common Minor Material	23,074		55		23,129	23,197	(68)
Purchased Services	12,969		0		12,969	14,184	(1,215)
Subcontract	661,100		0		661,100	641,248	19,852
Direct Delivery	0		25,790		25,790	0	
Burdens	143,727		1,290		145,017	146,056	(1,039)
Travel	25,307		225		25,532	27,355	(1,823)
Reproduction	6,395		41		6,436	4,794	1,642
Computer	70532		0		70,532	67,245	3,287
Interdivision	319		0		319	319	0
Others	3,496		0		3,496	75,016	(71,520)
TOTAL COST	$3,938,628		$41,210		$3,979,838	$3,948,488	$31,350

* Allowable costs to date + proposed contract modifications.

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